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CELESTIAL PHOTOGRAPHY AT A HIGH ALTITUDE.

H. C. WILSON.

During the past summer it was the writer's pleasure, with Professor Payne, to spend the months of July and August in the foot-hills of the Rocky Mountains in Montana, experimenting in celestial photography. One of the main objects of our expedition was to determine whether or not there might be great advantage for photographic purposes, especially the photography of the faint nebulous regions of the sky, in the high altitude which we could reach there over our moderate altitude on the Minnesota prairie. We wished to determine this by taking photographs of the same objects, with the same apparatus, using the same quality of plates, developed by the same person in as nearly the same manner as possible in both locations. The last condition could not be quite exactly fulfilled, because we could not transport our dark room, and the development at the temporary station had to be done without some of the conveniences which are to be found in a permanent dark room.

The location chosen was at Midvale, Montana, a station on the Great Northern Railroad just at the east edge of the first spur of the Rockies. Through the courtesy of the officials of the Chicago Great Western and the Great Northern Companies our party of four and baggage were transported free of charge to Midvale. Other interested friends contributed toward our expenses, but the fund was not large enough to permit us to go far from the railroad and to establish our station on the summit of one of the mountains as we might have desired. Considering the necessity of being near water and fuel, and of protection from the wind, as well as the convenience of being near a railroad station, we selected a small plateau 1,235 feet distant and a little north of west from the railroad station, surrounded by low hills and trees a short distance away, with the range of high mount-

ain peaks a few miles to the west shielding us from the prevailing west winds.

A part of this plateau and of the mountain range is shown in the engraving Plate XIX. Our sleeping tents are seen to the right of the center and the telescope near the right edge of the picture. The height of this plateau above sea level, as determined by a series of levels from a mark established by the U. S. Geological Survey, is 4,790 feet. A small mountain stream runs by the camp, in a channel approximately fifty feet deep, and our kitchen and dark room tents were located in the valley close to the stream. As a side matter I may state that this stream was well stocked with fine speckled trout, which was quite an important matter for our commissary department.

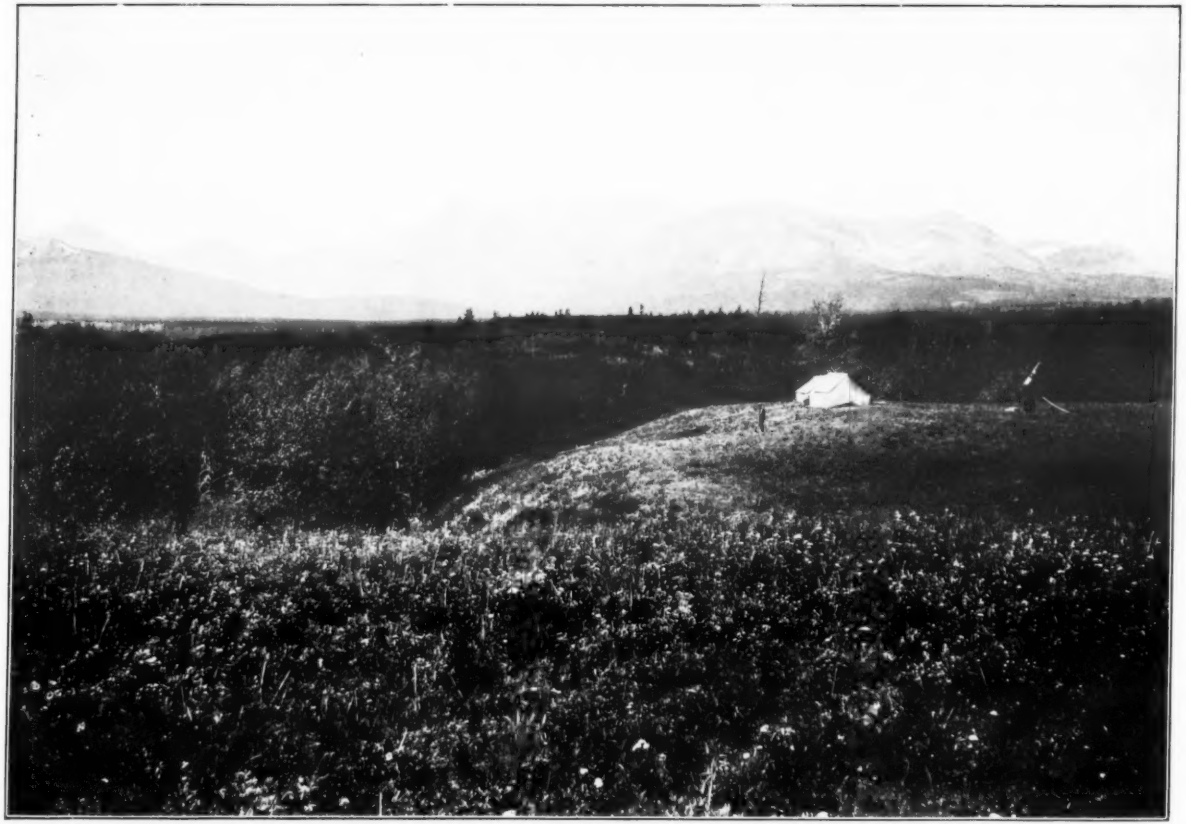
The high mountain in the central background of the picture, known as Mt. Henry, is between five and six miles distant. The top is a ridge nearly a mile long and very narrow. The general altitude of the ridge is about 8,400 feet and the sharp peak at the left end is about 8,850 feet above sea level. The round peak to the right and in front of Mt. Henry is a little over four miles distant and about 7,800 feet above sea level.

We should have liked to establish our station on one of these peaks, but the difficulty of transporting our heavy apparatus and supplies and the necessity of permanent shelter which would cost much more than our funds would warrant, prohibited the entertainment of such a desire. During August, when the smoke from forest fires filled the valleys and shut us off entirely from our work, we often wished we could have been located on the highest peak, which on the day we ascended it was quite free from smoke while the valleys were full.

The summits of these mountains are bare of vegetation, with the exception of some small mountain flowers and mosses which grow between the pieces of broken rock. Fuel and water would have to be carried up from one to two thousand feet.

Starting from Northfield on the morning of June 30, we had a delightful trip across Minnesota, North Dakota, and Montana, reaching Midvale on the morning of July 1. The drop off here was something of a shock, although we knew what to expect, for there is no village,—nothing but the necessary railroad station houses for telegraph operators and section hands, with one ranch in sight. After a few hours spent in examining the ground we selected our location and began to set up camp. On July 8 the instruments were in adjustment and the first photograph was taken on that night.

PLATE XIX.



THE CAMP OF PROFESSORS PAYNE AND WILSON AT MIDVALE, MONTANA.

The telescope and cameras, as set up at the camp, are shown in Plate XX. The day on which this photograph was taken, our last day but one at camp, was very smoky, so that the mountains are scarcely visible in the background.

We took with us the entire outfit of our 8-inch photographic telescope, with attached cameras, except the pier on which it is mounted. In place of the pier we set up two 10x12-inch pine timbers seven feet long, setting them 3½ feet in the ground and boxing in between them a well for the fall of the clock weight. These timbers formed a very steady support for the instruments and seemed to remain quite stationary during the two months although they were newly sawn out of green wood. In the engraving the reader will readily recognize the two telescopes of equal length, the 6-inch camera, of 36 inches focal length, projected in the picture against the lower part of the guiding telescope, and the 2½-inch camera, attached to the larger telescope near the upper end.

The telescope, as shown in the picture, was entirely out of doors and the only protection for it was an oilcloth cover which was wrapped carefully about the instrument when it was not in use. Fortunately there were no violent storms and very little rain during the two months. Fully half of the nights in July and nearly all of those in August were clear, except for the smoke from the forest fires. On every clear night the air was exceedingly quiet so that the telescope was seldom disturbed by a breath of air. During the day the wind was frequently quite strong and on a few cloudy nights it was such as to prevent our sleeping well in the tents. Several times the clouds which were running thick during the day would clear away just before the time for us to begin work at night and come on again in the morning. A very marked phenomenon on a few nights was the dissolving of great clouds, which rolled over the mountains toward us threatening to stop our work, but which entirely disappeared before reaching the zenith.

As a rule the ordinary clouds ran much higher than the mountain tops,—several thousand feet higher, I should judge,—but on two or three occasions when the weather was stormy they enveloped the mountains and sometimes detached clouds floated through the passes about 2,000 feet below the highest peaks. Twice fresh snow was deposited on the higher mountains, and once a tornado was seen passing several miles away.

Judging by the naked eye views of the sky the atmosphere ap-

peared strikingly more transparent than it does ordinarily at Northfield. Many more stars were visible at a glance, and the familiar stars appeared more brilliant. Near the horizon the difference was very marked, but perhaps that does not give a fair comparison, for the horizon all around us was elevated some degrees. In the direction of the mountains the elevation was over seven degrees.

During the clear days one could look close to the edge of the Sun and not notice much glare around it. The Moon stood out sharp and distinct so that some of the familiar craters could be recognized with the naked eye. The Milky Way stood out more in relief, the great patches being broken up into lesser ones more noticeably than here at home.

The color of the sky instead of being darker, as was anticipated from there being less suspended matter to reflect diffused starlight, was of a perceptibly lighter blue. The increased brightness of the sky did not, however, seem to diminish the apparent brilliancy of the stars. The impression given the writer was that of space not empty but filled with faintly luminous matter, not uniformly bright but with slight variations all over the regions distant from the Milky Way, and everywhere exceedingly transparent to the light of the stars.

In the great bright cloud of the Milky Way between β and γ Cygni one could count easily 16 or 17 stars besides the bright ones η and χ, while at Northfield it is difficult to distinctly see 8 or 9 with the naked eye.

Our first photographic experiments were upon the familiar object known as the America Nebula in the constellation Cygnus. This is a large diffuse nebula in the bright patch of the Milky Way about 3° east of α Cygni. It has been several times photographed by Wolf, Roberts and Barnard, and there are several excellent reproductions of it in *Knowledge*, notably the numbers for October and December, 1891 and July, 1902*. It was named the "America" Nebula by Dr. Wolf, who noticed on his first photograph of it, on Dec. 12, 1890, a striking resemblance between its outlines and the map of North America. The writer also had obtained photographs with both the 2½-inch and 6-inch cameras on the night of June 21, 1895, with an exposure of four hours, so that it is quite a fitting object for the purposes of comparison as well as being in one of the regions described by Herschel as filled with very extended nebulosity.

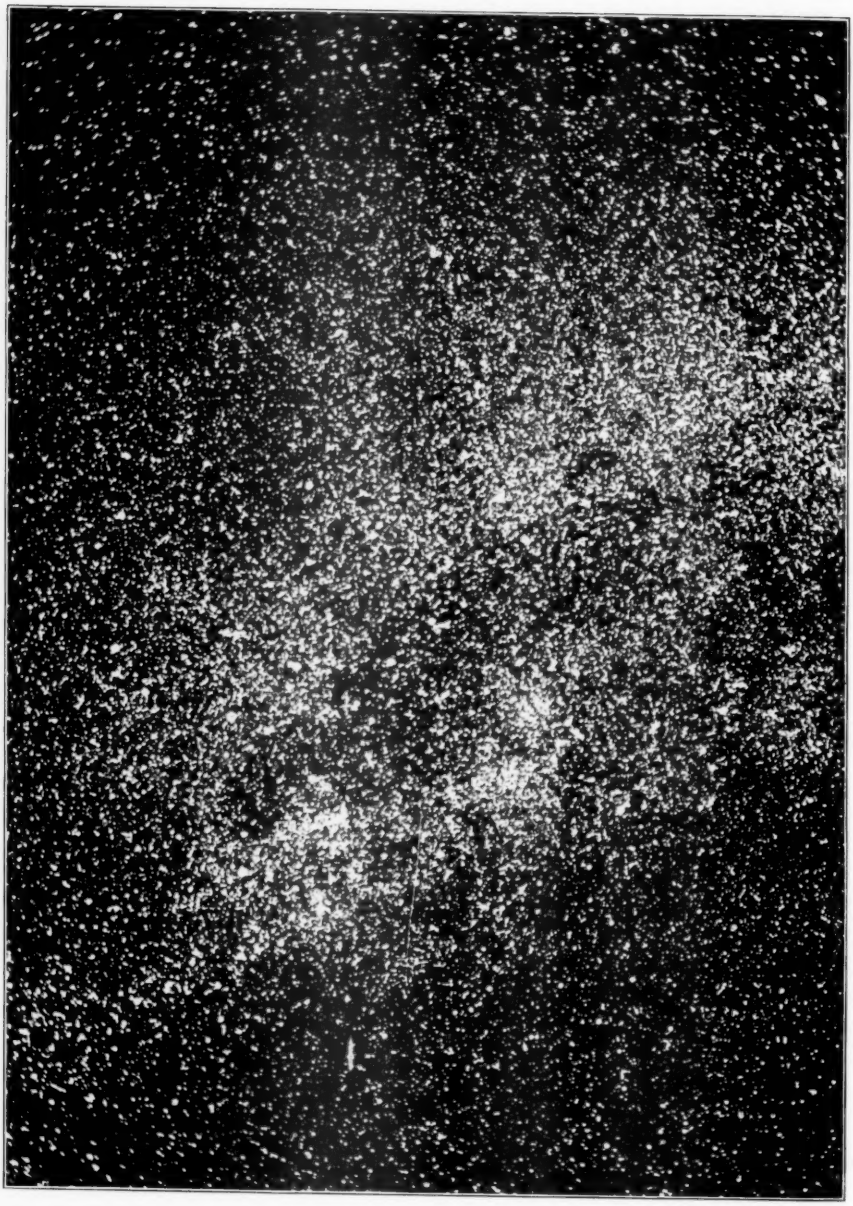
* See also *Monthly Notices R. A. S.* Nov. 1902, and Celestial Photographs by Isaac Roberts, Vol. II., Plate 24.

PLATE XX.

THE 8-INCH PHOTOGRAPHIC TELESCOPE AND ATTACHED CAMERAS AS MOUNTED AT MIDVALE, MONTANA.

THE 8-INCH PHOTOGRAPHIC TELESCOPE AND ATTACHED CAMERAS AS MOUNTED AT MIDVALE, MONTANA.

PLATE XXI.



THE MILKY WAY BETWEEN γ AND β CYGNI.

Photographed with a 2½-inch Darlot Lens at Midvale, Montana. Exposure 2 hours.

The negative from which Plate XVIII was prepared was obtained at Midvale, Montana, July 9, 1904, with a 2½-inch Darlot lens and three hours exposure. The reproduction is enlarged to nearly three times the scale of the original and only the central portion, which is comparatively free from distortion, has been included in the engraving. The area of sky covered in the engraving is about 14° long and 10° wide. The bright star image 1½ inches to the right from the center is that of α Cygni. The star ξ Cygni is in the dark space to the left of the nebula, about ⅜ inch below and ¼ inch to the left of the center; ν Cygni is an inch below the lower point of the "America" nebula, π^2 is just at the upper left hand corner of the engraving, while γ lies quite a little outside the lower right hand corner.

Not only is the region having the shape of North America full of nebulosity but a large area to the west of it is strewn with patches of faint light, and to the north and northwest it is impossible to tell where the nebula ends in the mass of faint stars. To give an idea of the faintness of this nebulosity let me say that an equally strong image of the outer loops of the Orion Nebula can be obtained with the same lens with an exposure of less than ten minutes.

More striking even than the nebula and the cloud of stars are the dark spaces and lanes or channels in the midst of the star masses. One of the darkest spaces of the northern half of the Milky Way lies just at the left of the "America" nebula. It is very conspicuous to the naked eye on any clear moonless night just now, being overhead in the early evening. Two rather bright stars lie close to its center line but faint stars are remarkably few. At the right of the nebula the spot corresponding to the Gulf of Mexico, in fact the whole "Atlantic coast line," is remarkable for the absence of stars. On the north is a row of approximately parabola shaped bays encroaching upon the nebula and the star cloud and connecting with them a crooked dark channel runs to the north edge of the plate. Across the left hand portion of the plate are other remarkable arrangements of star clouds and dark channels which are well worthy of study.

At Midvale three photographs of this region were taken with the 2½-inch camera with exposures of one, three and four hours respectively. Plates were exposed at the same time in the 6-inch camera and the 8-inch telescope. Unfortunately in handling the large plates exposed in the 6-inch camera, in the small and inconvenient developing box which we had at the camp, I at first fogged them slightly, so that they are not suitable for reproduc-

tion, and the scale of the picture given by the 8-inch is too large for such faint nebulosity to make much impression on the plates.

The three plates exposed in the 2½-inch camera are all good and show the same general outlines of the nebula. The density of the negatives seems about proportional to the duration of exposure. With the longer exposures the fainter portions of the nebula are filled in and the outlying patches are enlarged. Both the three and four hour exposures appear to give all of the nebulous area shown in the reproduction of Dr. Wolf's photograph in *Knowledge*, Dec. 1, 1891, which was taken with a portrait lens and an exposure of thirteen hours.

My first impression on developing the one hour exposure was that it was equal to the four hour exposure at home, but a careful comparison of the plates shows that the gain is not nearly so great. At first sight the three hour photograph at Midvale appears to be equal to the four hour at home. There is a slight difference in the development of the two negatives, and allowing for this I conclude that one hour of exposure at Midvale will give about the same result as two hours at Northfield.

I reach the same conclusion by comparing a two hour exposure made on the great star cloud between β and γ Cygni made at Midvale with a four hour exposure made at Northfield in 1894 and one of two hours made since our return, with the same instrument. A comparison of the photographs taken with the 6-inch Brashear camera confirms the conclusion that in the increase of altitude of nearly 4,000 feet there is a decided gain in the impression made upon a photographic plate by stars and nebulæ with a given duration of exposure.

Plate XXI has been prepared from a negative exposed for two hours, at Midvale, on the night of July 20, 1904, with the 2½-inch Darlot lens. In reproduction the photograph has been enlarged nearly three diameters and only the central portions are retained in the engraving. The area of sky covered by the engraving extends from near β Cygni at the lower right hand corner to near γ Cygni at the upper left hand corner, thus including the major part of the great star cloud of the Milky Way lying between the two stars named. Neither of these stars are included in the picture, γ lying ¼ inch above and ½ inch to the right of the upper left hand corner and β being ⅔ inch below and an inch to the left of the lower right hand corner of the plate. Within the area shown Heis' Atlas gives 2 stars of the fourth magnitude, 12 of the fifth and 17 of the sixth. It is, however, difficult on an ordinary night for a person with average eyesight

to distinguish more than 8 or 10 of the stars, the fainter ones being hidden in the glow of the thousands which are just a little beyond the limit of vision.

In this great star cloud too are seen the curious dark patches and lanes, to which attention was called on Plate XVIII. Two explanations are offered for these, the one that they are really, as they appear, vacant spaces void of stars, through which we see into empty space beyond, the other that they are produced by the intervention of enormous clouds of dark matter between us and the stars of the Milky Way, absorbing and cutting off their light. The latter view was strongly advocated some thirteen years ago by Mr. A. C. Ranyard, then Editor of *Knowledge*, but is not generally accepted among astronomers.

During our stay at Midvale, we made exposures, on two nights each in July, on Herschel's regions Nos. 43 and 45, α 20^h 53^m 15^s, δ + 16° 44′ and α 20^h 57^m 34^s, δ — 1° 34′ and also, on two fairly clear nights in August, on the region No. 48 near ϵ Pegasi. The plates all show feeble variations in density of the skylight in the regions indicated by Herschel, but we have not yet found time to copy them and bring them out with sufficient intensity to decide whether the duplicate plates agree in detail or not. We hope to find time to make this test during the coming month.

THE MATHEMATICAL THEORY OF ECLIPSES.

WM. W. PAYNE.

"The mathematical theory of eclipses according to Chauvenet's transformation of Bessel's method, explained and illustrated" is the full title of one of the most important and useful books for the student in practical astronomy that has been published in many years. The author of the book is Roberdeau Buchanan who was assistant in the Nautical Almanac Office, Washington, D. C., for twenty-three years and is also author of a small book, titled "A treatise on the Projection of the Sphere." The publishers are J. B. Lippincott Company, Philadelphia.

This new book which bears impress of March 24, 1904, contains 247 pages, finely printed on heavy book paper, in clear type of about the same size as that used in Chauvenet's Spherical and Practical Astronomy, published more than forty years ago by the same well-known printing house. Its indexes, tables and illustrations are evidence that its author knows well, in the line of this work, how to arrange reference matter for the con-

veniences of a hand book, that seems to leave little or nothing for the most exacting of the mathematicians to desire. We are very agreeably surprised at the thoroughness of detail and the completeness of the work as an aid for self instruction in the study and computation of solar and lunar eclipses, transits of Mercury and Venus and the occultations of the fixed stars. Chauvenet's Spherical and Practical Astronomy is incomparably the greatest work, on this subject, that has ever been published in the English language. Like other great authors in mathematics, Chauvenet is not always clear and definite and complete in the discussion and illustration of sound theory. Analytic powers of mind of a high order easily make long steps in legitimate argument, that can not readily be followed by those who have less experience or less mental grasp naturally. After more than a score of years of experience in computing eclipses for the Nautical Almanac, in which time, the author of this new book must have gone through the whole cycle of eclipses belonging to one Saros, he certainly has had the opportunity to gain a knowledge of details which can possibly come to no one else who has not studied this matter in the same way.

In view of these facts we have read this book through somewhat carefully and have compared the positions taken by the author with those made by Chauvenet in his Astronomy to satisfy ourselves that the important claims made in the book before us are well supported in fact.

Some of the points made by the author are that the theory of eclipses is one of considerable intricacy, and while the student can generally follow Chauvenet in deducing the formulæ, yet he meets with some difficulty in grasping the subject, finding many points requiring further explanation than is given in the text. Whenever this occurs no other publication will be of the least assistance in explaining this part of Chauvenet's work.

Another difficulty is met by the practical computer, however well skilled he may be in formulæ or computing, and that is, the formulæ of Chauvenet are not developed in the order they are to be used in computing eclipses. They are so numerous and so scattered that it is necessary to write them out in order before the computation of an eclipse is undertaken.

Again in Chauvenet's elegant treatise the formulæ are so rigorously exact, that many of them may be considerably simplified and the labor of using them thereby diminished. It is useful and encouraging to know when and how such work may be done. The author has undertaken to do this in some cases and

he plainly indicates the advantages arising from such steps.

One of the most impressive features in this new book is the use of graphic method employed in explaining complicated formulæ. We have nowhere else seen the use of this method so fully and effectively given as in Mr. Buchanan's work. Modern mathematics for the last few years has been emphasizing this way of presenting the results of intricate problems, in different lines of scientific research especially where lines and curves of continuity play some important or unique part.

This new book seems to us to deserve a fuller notice than the general statement we have already made, that our readers may know somewhat more in detail the features of it and the ground it covers. The first section speaks of the two methods of computing solar eclipses, that have been in use; the first and the earlier considered the Sun and Moon as tangent to one another externally, and the distance between their centers was the arc of a great circle equal to the sum of their radii. By this method, given the place of the eclipse, find the times. Only one place on the Earth's surface could be used in computation at once. The second method was exactly the converse of this: given the time, and the place on the Earth's surface where the phenomenon is seen will be found. In other words assume a series of times, and all the points on the Earth's surface where the same phenomena are visible may be made known, an advantage not possessed by the former method. Those acquainted with the history of this subject will remember that the genius of Bessel in 1841-42 planned and devised the remarkable formulæ that have been accepted as the best for the last sixty years and more. Hansen in 1858 presented a different method, but Professor Chauvenet in 1863 said: "As a refined and exhaustive disquisition upon the whole theory "Bessel's *Analyse der Finsternisse* in his *Astronomische Untersuchungen* stands alone." It might be expected from Chauvenet's opinion of Bessel's work, that he would make it the basis of his own standard works in astronomy that were published later; and, since this new book makes Chauvenet the basis of its plan and general methods for the computer, it would be expected that about the same order would be followed here. So in the second section the criterion of the solar eclipse is considered, and specific directions are given for interpolation, even to the logarithms to be used in computing first or second differences.

We notice with interest what is said on page 27 about *I*, the inclination of the Moon's orbit to the Ecliptic. Chauvenet does not show how to get that quantity, neither does the Nautical

Almanac give it, but, in a few words this author's suggestions plainly open the way for a student without experience.

This author thinks that the values given by Chauvenet on page 438 of his Practical and Spherical Astronomy need revision, the Moon's least parallax being in error at least one minute. The author comes to this conclusion after consulting Professor Ruel Keith who has computed the Moon's semi-diameter and parallax for the Nautical Almanac for thirty consecutive years, who said: "the Moon changes its distance so irregularly that it is hard to follow it by rule," and the author says "I then take the extreme values of the Moon's parallax from all the eclipses I have computed from 1883 to 1905, both years inclusive. * * * These extremes may not be the greatest possible, but they are at least better than those heretofore given as correct, for the greatest value is greater than that given by some authorities, and the least value is less." Then he gives a table of values of these quantities, from many authorities that have claimed attention during the last fifty years, showing why particular values have been chosen.

Speaking of the Saros in connection with the criterion, the author calls attention to a misprint in Newcomb's Popular Astronomy, 1878, p. 30, which gives the length of the Saros as 19⅔ years when it should be 18⅔. The suggestions at the close of the section for making a search for the eclipses of a given year are helpful and apparently complete.

In section third the reader will find the data and the elements for the solar eclipse taken up in an orderly way. The example given is the total solar eclipse of 1904, September 9. The six quantities required for all eclipses are first mentioned and they are interpolated by the usual formula to first, second or third differences, as is needful for them respectively to fulfill the part of the work necessarily dependent on them. In his remarks on this first step of the computation, the author calls attention to a principle in the theory of differences which seems to have been overlooked in ordinary works on interpolation. It is regarding the quantity Δ, that it is distributive in differences of right ascension of the Sun of any order. This fact may be made use of as a check in numerical operations, as well as a means of shortening the work in certain methods of computation. A similar statement may be made about the Moon's declination.

Attention is also called particularly to the eclipse constants, the Sun's parallax and semi-diameter, the ratio of the Moon's equatorial radius to that of the Earth and irradiation. The

authorities for these constants are given, when they came into use, how almanac officers in England and America have changed them and used them in recent years.

Section four has to do with the eclipse tables, and it is a very important part of the book which precedes the commencement of the work for the eclipse itself. The computer is told how to use the constants in actual work, how to employ the Zech's tables of addition and subtraction, logarithms expeditiously and a great number of other details that is helpful for any one to know if he would use the best ways of computation only to a limited extent.

The author has carried the example before mentioned through all the details of this table work, to illustrate in the best way possible just what he means in a real case of computation by the verbal decriptions in his text. At the close of this section he tells howto illustrate the eclipse generally by geometrical methods and gives a full page plate of the drawing belonging to the example in hand. His methods of projection are full and clear and seemwell adapted to the matter in hand.

In working out this particular eclipse in detail, the author refers to a great number of other eclipses which he has computed to show how the work will vary in these different cases and he remarks distinctly where exceptions to general rules must be made. We have been impressed by the knowledge that the author shows in the descriptive part of his book about the whole theory of eclipses, as presented in the details of computation to reach the varying conditions that must be met in going through a whole cycle of eclipses in a single Saros. The attention that is given to details in this matter goes so far as to call the attention of the student to the fact that it is necessary to avoid mistakes in regard to signs for algebraic operations in particular cases, also giving instruction in regard to the signs that belong to the quantities as such.

We notice with satisfaction and interest that the plan of the author in his illustrative examples is that which is in use by the best practical and experienced computers with whom we are acquainted. First to write out all the formulæ needed for a particular partial step in the solution of a problem, and then to put the terms to be computed in vertical columns with the number of the formulæ in the first, and the quantities in the next, and the signs of operation and of character with the logarithms in another column, so that every part of the work is as orderly and definite as the most logical verbal argument could be if con-

structed by a masterly logician. Every experienced scholar in the higher mathematics knows that this is the way to write mathematics so that any one may read the work of a computer as he would a printed argument from a lawyer's brief or a story written by a novelist. Putting mathematical arguments in this way makes the writer or reader to understand just what he is doing, and why he is doing it. This is mathematical training in the largest and best sense. In the choice of logarithmic tables for the computing part of the work, the author has made some excellent suggestions, the substance of which, we know, have been overlooked by some good scholars and teachers in very recent years. As before indicated, in a single sentence, so now in all parts of the illustrative example of the eclipse of 190-, September 8, the author decides what tables as to number of decimal places in the mantissa should be used, and gives his reasons for the suggestions made in this particular. Not long ago a student who had received some instruction at Goodsell Observatory in computing the orbits of comets, and who later attendd one of the largest and most popular Universities in the United States, wherein special courses in practical astronomy are advertised and taught, did further work in the same lines in that Institution. Any practical computer can well imagine that student's surprise when directed by the instructor to use seven-place tables for some work on a comet orbit, in regard to whichfour-place logarithms would have been much better every way. It is just such practical and useful and time-saving knowledge as this that the student wants and should have in preparation forrapid and efficient work in any scientific pursuit.

Another of the strong points in this new book whic ought to be referred to more fully is the use that the authormakes frequently of graphic illustrations in the course of exlaining the meaning of intricate formulæ. It is one thing to tak a formula as it may be given by an author, and compute a problem by it accurately, but it is quite another thing to do the same work in the same way, having fully understood beforehand the full meaning of the analytic structure of the equations that re being so used. These geometrical figures and the full explanations that accompany them not only give the student a full ar clear meaning of what the author has been doing and whatie himself is trying to do, but they add to and maintain hisown interest while he is pushing his way through mazes of analytical transformations which often trouble good mathematicins to understand unless by some such aid as that furnishedby graphical

methods. We earnestly commend this excellent feature in this new book.

In Section twenty on the shape of the eclipse shadow on the Earth, several things are found worthy of especial notice. It is as a whole mathematically one of the strong parts of the work. In the beginning of this section is given Professor Bigelow's theory of the "shadow bands," so-called, which are usually seen near the beginning and end of totality in solar eclipses. After a study of the total eclipse of May 28, 1900, Professor Bigelow of the Weather Bureau, Washington, came to the conclusion that these "shadow bands," were caused by the undulations and disturbances of the density of the atmosphere within the cone of the shadow due to the lower temperature within the cone which may fall five or six degrees thereby producing intermittent opacity. So far as we know this explanation of that curious phenomenon of the shadow bands is new. Astronomers generally have not been agreed as to their cause, but they have commonly attributed this display of color to the effect of diffraction of the Sun's light as it passes by the limbs of the Moon, a very natural inference, but so far lacking the sufficient observational proof to warrant acceptance.

We think enough of this new book to adopt it as one of the hand-books of reference in the post-graduate course of study in Mathematics and Astronomy at Goodsell Observatory which will soon be opened again for students wishing to prepare themselves for instruction in either Mathematics or Astronomy, or for places in Observatories contemplating either oversight of such institutions or practical work therein.

PHOTOGRAPHY OF THE HEAVENS.*

ON THE ACCURACY OF THE POSITIONS OF THE STARS OBTAINED BY MEANS OF PHOTOGRAPHY. NOTES OF G. BOCCARDI. COMMUNICATED BY CORRESPONDENT A. RICCÒ.

Every one knows that the application of celestial photography to the compiling of star catalogues has notably shortened the labor; but perhaps all have not realized the degree of exactness which can be secured in the photographic positions of the stars, a degree which is far superior to that of the positions given by the better catalogues and depending on many meridian observations.

The illustrious Monsieur Loewy in various memoirs recently published has examined and discussed the different causes of

* Translated by Miss Lucia E. Danforth, Red Wing, Minn.

error, which, although in a slight degree, exist in the photographic positions of the stars. The conclusion at which he has arrived in the above-mentioned memoirs in the Introduction to Volume I of the Photographic Catalogue of Paris is that in the error which remains in the photographic positions of the stars are involved the following factors:

1st. The inexactness of the measures of the rectilinear co-ordinates of the stars on the plate.

2nd. The inexactness resulting from the nature of the thin gelatine film which covers the plate; that is to say, of its varying degree of sensitiveness in the extention of the single squares of the reticule impressed on the plate and the irregularity which the film shows. According to Loewy the error produced by this physical cause in the measurement of the co-ordinates is hardly appreciable above the tenth magnitude but for the stars below the tenth magnitude it is appreciable, and about equal to the error arising from the same measurements, and it increases rapidly as the size diminishes.

3rd. The uncertainties which remain in the adopted positions in equatorial co-ordinates for the comparison stars selected on the plate to determine the constants and the corrections to the measures.

Being charged with the reduction in the stellar catalogue of the celestial photographs obtained in the Royal Observatory of Catania, by the Director, Professor Riccò, and by the engineer, Signor Moscari, I have had occasion to occupy myself also with the degree of accuracy which can be obtained in the photographic stellar positions. To determine this accuracy I have preferred a practical method, the general principle of which consists in comparing the divergences between the photographic position of a star given by the different observatories with the divergences between the positions of the same star given also by the different observatories and depending on observations of the meridian circle. In making the comparisons between the photographic and meridian divergences I do not take up mean or probable errors of the two classes of measurements, because, if through the meridian positions it was possible to calculate the errors according to the method of least squares, having many meridian positions of the same stars, given by different observatories, this was not possible through the photographic positions, since the same star has rarely been photographed at several different observatories, and the photographic results have rarely been published. In fact, I have not been able to institute a com-

parison except between two, or at most, three, photographic positions of the same stars. I have therefore believed it preferable to calculate through the two kinds of measurement the differences from the mean and to compare them with each other.

With regard to the meridian positions Monsieur Loewy, basing the calculation on all the meridian positions of 21 reference stars for *Eros* has calculated the following probable errors:

$$\text{in } \alpha \quad \pm 0''.350 \qquad \text{in } \delta \quad \pm 0.''332$$

But this result is not general, as the probable error varies much according to the stars and also differs slightly with the declination. It may be seen that in 42 stars of *Eros*, employed by me in one of the proofs made, we have through the average difference of one meridian position given by one observatory from the average of all the positions given by many observatories

$$\text{in } \alpha \quad \pm 0''.69 \qquad \text{in } \delta \quad \pm 0''.36$$

In another group of 18 stars of *Eros* I find average difference:

$$\text{in } \alpha \quad \pm 0''.84 \qquad \text{in } \delta \quad \pm 0''.42$$

The comparison of the differences relative to the photographic and meridian positions can be made through every star in particular, and then the influence of the magnitude disappears; that is one can have in every magnitude an exact idea of the accuracy of the two methods. Besides, having compared the positions of about all the stars below the eighth magnitude and above the tenth magnitude the average of the differences for the different stars can give an exact idea of the degree of precision which can be obtained with such small stars. As the meridian positions of every star for Eros given by the different observatories are based on nearly the same number of observations I have not paid any attention to the smaller differences which can be obtained from a diversity in the number of observations.

I refer here only to a few of the many experiments made by me to determine the accuracy of the photographic positions.

I. I have compared together the photographic positions of 42 comparison stars belonging to the plates of the Observatories of Paris and Bordeaux taking the relative data of circular No. 10 of the Observatory of Paris. The stars were DM 53^0,470 and these following in the Circular (p. 162) as far as 52^0,609. I have calculated the differences in α and δ between the photographic positions given at Paris and those given at Bordeaux. Without recourse to squares I have formed the arithmetical mean of the absolute differences in α and δ obtaining the respective values $\pm 0^s.0210$ and $\pm 0''.197$.

The difference of one photographic position from the mean of two photographic positions is half of these values, that is $\pm 0^s.0105$, $\pm 0''.0985$. Continuing this process for each of the forty-two stars I have formed the differences between the meridian positions given by the different observatories and the mean value; that is the average of these positions (as has been calculated at Paris) and in the same manner as through the photographic with each of these stars I have calculated the average of these differences, dividing, that is, the sum of the differences of the average taken in absolute value, by their number.

Adding all these averages of the relative differences for all of the 42 stars, I have divided the sum by 42 and have obtained thus through values of the differences of one meridian position from the mean $\pm 0^s.0461$, $\pm 0''363$.

Inasmuch as the photographic positions given by the two observatories as well as the meridian positions furnished by many observatories were obtained at the same time, that is in the second month of the year 1900, a comparison between the results of the two methods is legitimate. Then, since the average differences obtained as above are approximate to those which are obtained by using the squares if it is believed that by applying also in this case the criterions of the method of the least squares, to judge of the relative exactness of the two kinds of measurement, one will find that in the case cited the exactness of the photographic positions is in α more than 16 times as great as that of the meridian positions; in δ a little less than 16 times as great. But this proportion varies with different cases.

II. The second proof which I give is based upon a consideration of a somewhat different character, that is to say by comparison of the maximum difference from the several photographic positions of a star with the maximum difference from the meridian position given for the same star by different observatories. I have by my method reduced the plates Nos. 775 and 1856 of Catania comparing nine stars and for each of these stars I have adopted for the photographic position the average of the results of the two plates. As the photographic positions of these nine stars obtained at Paris are given in the Circular quoted and for four of these also the positions obtained at Bordeaux I have for each star compared together the photographic positions of Paris, Catania and Bordeaux, when they existed, and written for all the nine stars the greatest difference between the photographic positions of the Observatories mentioned. I have afterward in another place compared together

for each of the nine stars the meridian positions obtained in different observatories, on occasion of the observations of *Eros* and also written for each star the maximum divergence.

The results are found in the following table in which the small numbers written below the seconds of the right ascension photographed at Paris, Bordeaux and Catania, indicate the number of the plate on which the photographic position depends:

	Photographic Position for 1900.0					Photographic Position for 1900.0				
DM No.	Paris	Bordeaux	Catania	Diverg. Photograph.	Diverg. merid.	Paris	Bordeaux	Catania	Diverg. Photograph.	Diverg. merid.
	h m s	s	s	s	s	° ′ ″	″	″	″	″
48,746	2.37.22,085 2		22,073 2	0,012	0,06	48.48.20,30		20,58	0,28	1,2
48,750	" 38.56,222 5		56,244 2	0,022	0,15	48.32. 8,16		7,98	0,22	1,2
48,760	" 41.25,413 5	25,398 5	25,396 2	0,017	0,06	48.48. 6,30	6,21	6,51	0,30	0,9
47,700	" 41.43,828 4		43,840 2	0,012	0,23	48. 2. 9,92		9,64	0,28	1,2
48,762	" 42 1,295 5	1,274 2	1,267 2	0,028	0,18	48.45.58,93	58,77	59,44	0,67	0,8
48,763	" 42.27,528 4	27,523 5	27,498 2	0,030	0,28	48.53. 4,87	4,55	5,14	0,59	1,2
48,764	" 42.43,272 5		43,241 2	0,031	0,12	48.27.49,24		49,21	0,03	1,2
48,770	" 44.19,649 2	19,659 4	19,649 2	0,026	0,33	48.56.10,40	10,07	10,58	0,51	1,4
47,714	" 44.39,926 4		39,926 2	0,017	0,09	48. 5.32,45		32,22	0,23	1,4
			mean ±0.0217		±0,167			mean ±0,346		±1,167

The meridian divergences are given with one cipher less, because the positions given by the different observatories come in the end to about the same result. The error of the photographic positions of Bordeaux for five of the nine stars can not perhaps be found

by the method which follows, because the positions of Catania being based upon only two plates obviously preclude the possibility of having the highest divergency determined from them. It is proved partly by the preceding table but more by comparing the photographic positions of Paris and Bordeaux through the whole series of stars of Circular No. 10, through which generally the divergencies are less than those resulting from the nine stars between the two observatories.

The preceding table establishes the fact that the average of the highest divergencies between the photographic positions is in α nearly eight times less than the corresponding average in the meridian positions. In δ it is more than four times less. Thus the great superiority of the photographic positions over the most exact meridian positions is evident.

III. Another important fact which results from a comparison of the photographic positions with these, is that the accuracy of these increases a little by multiplying the number of the plates on which they are found. This may be gathered from the preceding table, but more by comparing the photographic positions of Paris and Bordeaux relating to the forty-two stars which we have mentioned.

From these, to cite several examples, it is seen (Circular No. 10, p. 163) that for one star the photographic position of Paris based on twenty-five plates differs from that of Bordeaux based on seven plates, by $0^s.023$, $0''.003$: for another star the positions of which depend respectively on 28 and 10 plates, the differences between those given by the two observatories are $0^s.012$, $0''.028$. On the other hand for one star based on three plates in Paris and three in Bordeaux, the differences are scarcely $0^s.012$, $0''.19$ and such examples can be multiplied.

I have found a confirmation of this fact in the examination of the differences existing between the meridian positions adopted for the stars of comparison and the photographic positions of the same stars. In fact if we compare the given results through the stars reduced in the different observatories with a much different number of plates, we find that these results are not much different from each other. Therefore it is of little assistance to multiply the number of plates on which the photographic position is found.

Not to have recourse to other examples, I give in the following table for the nine stars of which I have before spoken: The residual differences, the meridian position, the photographic position, for Paris, Bordeaux and Catania. It should be noted that the

meridian positions for which I have compared the photographs are those adopted respectively in those three observatories. Also in the following table the small numbers written under the seconds of the right ascension indicate the number of the plates on which the respective photographic position depends. It should be noticed also that the rectilinear co-ordinates of the stars on the plate were deduced at Paris from the measurement of the two photographs of any star each measured two times and these four measurements were repeated in four orientations, differing by 90 degrees. The co-ordinates of Catania depend on the measure of one photograph alone made only one time in one position and another time in a position at an angle of 180 degrees.

Differences between the meridian and photographic positions.
(Sign: merid.—photograph).

through α			through δ		
Paris	Bordeaux	Catania	Paris	Bordeaux	Catania
s	s	s	″	″	″
+ 0,053 (2)		+ 0,049 (2)	+ 0,07		+ 0,19
− 0,017 (5)		0,000 (2)	− 0,14		− 0,41
− 0,011 (4)	− 0,025 (5)	− 0,035 (2)	− 0,03	− 0,13	+ 0,10
+ 0,008 (5)		+ 0,019 (2)	− 0,10		− 0,36
− 0,020 (4)	− 0,032 (2)	− 0,046 (2)	+ 0,15	− 0,04	+ 0,55
+ 0,009 (6)	+ 0,008 (5)	− 0,019 (2)	+ 0,08	− 0,10	+ 0,23
− 0,007 (5)		− 0,047 (2)	− 0,19		− 0,25
+ 0,005 (2)	+ 0,011 (4)	− 0,021 (2)	+ 0,50	+ 0,33	+ 0,73
− 0,021 (4)		− 0,047 (2)	+ 0,03		− 0,26

IV. The last comparative table which I consider, refers to the photographic and meridian positions of eighteen stars by comparing Plate No. 2057 of Catania. Of these same stars we have only the photographic positions obtained at Bordeaux, not with one plate alone as in Catania, but with several. The stars given were not photographed in Paris. In the following table I give for every star the differences from the photographic position given by the two observatories and afterward the maximum differences from the meridian positions given at the several observatories, naturally, because the comparison of the two classes of measurements to be legitimate would have to compare the photographic positions not of two observatories but of several.

Therefore, it has not been possible for me to obtain the data necessary for that. In any case it may be deduced from the preceding tables that the maximum photographic difference, in case of many observatories would not be preceptibly greater than those from the positions of Bordeaux and Catania, the highest differences of which are caused partly by the difference in times at which the plates were photographed. In fact the average period of the Bordeaux plates is 1900.8, while the Catania plate was taken by Professor Riccò, August 28, 1903. The meridian plates, however, between which I give the maximum differences, all refer to the same period.

D. M.	Photographic Position for 1900.0				Difference		Maximum diverg. from the meridian position	
	Bordeaux	Catania	Bordeaux	Catania	Bordeaux	Catania		
	h m s	″	° ′ ″	″	″	″	″	″
51,317	1.24.26,147	26,135	51.34.41,71	41,35	+ 0,012	+ 0,36	0,17	2,6
49,401	24.37,849	37,821	50. 9. 7,16	7,30	+ 0,028	— 0,14	0,14	1,4
49,400	24.38,426	38,401	50. 5.56,10	55,81	+ 0,025	+ 0,29	0,15	2,2
50,297	25.41,687	41,693	50.55.13,84	14,82	— 0,006	— 0,98	0,13	1,1
50,298	26.12,652	12,714	50.38.51,85	51,90	— 0,062	— 0,05	0,13	2,2
50,299	26.22,631	22,648	50.18 34,51	35,04	+ 0,015	— 0,53	0,13	1,4
50,300	26.48,642	48,656	50.58. 5,01	5,10	— 0,014	— 0,09	0,30	1,5
50,301	26.59,920	59,945	50.22. 1,17	1,61	— 0,025	— 0,44	0,34	1,4
51,331	27.58,708	58,722	51.19.13,29	12,59	— 0,014	+ 0,70	0,12	2,5
49,414	28.19,574	19,582	50. 1. 1,62	1,92	— 0,008	— 0,30	0,23	2,1
51,334	28.33,783	33,808	51.38.28,99	28,55	— 0,025	+ 0,44	0,18	1,0
51,338	29.22,542	22,581	51.39. 7,87	7,25	— 0,039	+ 0,65	0,31	1,7
49,416	30. 5,718	5,705	50.12.23,77	24,43	+ 0,013	— 0,66	0,27	1,2
51,339	30.24,396	24,383	51.14.15,90	15,80	+ 0,013	+ 0,16	0,22	0,8
50,314	30.44,606	44,581	50.44.59,37	59,94	+ 0,025	— 0,57	0,21	0,6
49,442	31.42,180	42,178	50. 5.47,45	47,60	+ 0,002	— 0,15	0,24	3,4
51,357	33.13,708	13,651	51.45.32,45	32,19	+ 0,057	+ 0,26	0,33	7,9
51,363	34. 2,612	2,551	51.21.27,81	27,56	+ 0,061	+ 0,25	0,26	1,8
				mean:	± 0,0247	± 0,387	± 0,2144	± 1,711

Recapitulating, these are the principal conclusions at which we have arrived.

1st. If the rectilinear co-ordinate of only the larger image of a star (of the two images obtained in Catania) are measured in one position of the star, and if the measurement of the same image is repeated in a position 180 degrees from the first, the average of the values obtained by the comparison of the star in two positions of the plate is more exact than the average which would be obtained by always measuring in the same position two photographs of the star, each one twice, as is done, for example, at Paris.

2nd. Not having taken for examination stars of less than the tenth magnitude I have not been able to determine the error depending on the film of gelatine. However, although the fact that so far as the tenth magnitude the differences (relative to the same star) between the photographic positions obtained in the different observatories and the meridian positions are approximate seems to prove that so far as this magnitude the influence of the film is not appreciable, we can not admit that on the plates of the different observatories the effects of this cause of error are equal.

3rd. The accuracy of the celestial co-ordinates of the stars of comparison deduced from the plates, is always in the right ascension at least ten times as great as that of the positions depending on different observations of the meridian circle. Often the accuracy is more than fifteen times as great. In declination the exactness of the photographic positions is at least four times as great as that of the meridian positions. Often more than seven times as great.

4th. As a result of the investigations made in Catania and elsewhere, that the exactness of the photographic positions of the stars not used as reference stars to determine the constants of the plate is inferior to that of the positions of the stars of comparison, about in the proportion of one to two, one can say that the exactness of the photographic positions of a given star is in ascension at least five times as great as that of the meridian positions; in declination at least twice as great. It is well understood that this refers to the plates, the constants of which were determined by from ten to twelve comparison stars. From plates on which can be found twenty or more stars of comparison the exactness of the photographic positions is about the same for all the stars of the plate.

THE LEONIDS.

WILLIAM H. PICKERING.

For Popular Astronomy.

It has already been shown in Popular Astronomy, 1902, X., 8, 400, and 1903, XI., 6, that the maximum condensation of the Leonid shower, during the present thirty-four year period, was not due before 1901, and that it probably appeared in that year. The meteors then presented themselves in countless numbers as seen from the southern borders of the United States. It was also pointed out that while a considerable shower was to be expected in November for several successive years, that this shower would appear in different longitudes upon the Earth, the maximum density moving west about seven or eight hours each year. Thus for 1902 it was predicted for Japan, and for 1903 for Arabia and the Mediterranean. In 1902 no shower was recorded, but in 1903 a large number of meteors were observed in Greece and also in England. The English observers consider the shower of 1903 the finest of the present series. Mr. Denning states that at the maximum, the number of meteors visible to a single observer must have been in excess of 200 per hour, *Monthly Notices*, 1903, LXIV., 125.

At Harvard we have hitherto observed two maxima, one in 1898 and the other in 1901. Another is expected, therefore, this November. Whether it will equal or surpass the two others, there is of course no means of knowing. The results of the English observers might lead us to expect a considerable shower, since it was more than three times as dense as that of 1901 as observed at Harvard, while the latter was about twice as dense as the shower of 1898. On the other hand more brilliant fire-bells appeared in 1898 than in 1901. In any case nothing is expected to be seen before midnight of the night of November 14-15, and the greatest density is not looked for before 4 A. M. It is fortunate that there will be no Moon to interfere with the observations. While the writer is not prepared to predict anything more than a moderate shower, this letter has been written in order to warn observers who may be interested in such matters, that such a shower is due, and that it is possible that it may exceed in density anything that we have yet seen.

REDUCTION OF 295 PHOTOGRAPHS OF EROS MADE AT NINE OBSERVATORIES DURING THE PERIOD 1900 NOVEMBER 7-15, WITH A DETERMINATION OF THE SOLAR PARALLAX.*

ARTHUR R. HINKS, M. A.

§ 1. *Introduction.*—In two previous papers (*Monthly Notices*, 1901 November and 1902 June, vol. lxii. pp.22 and 551) there is an account of the experimental reduction of certain photographs of *Eros* made at Cambridge, Lick and Minneapolis. Its object was to test a method of reduction in rectangular co-ordinates; and the conclusion was that the method was simple, convenient, and worthy of a more extended trial. I therefore ventured to propose that we should undertake at Cambridge the reduction of so much of the photographic material obtained during the period 1900 November 7—15 as might be placed at our disposal by the kindness of the directors of the different observatories taking part in the co-operation to observe the planet *Eros* at that opposition. At the time this proposal was made we had very little information as to the real accuracy of the photographic method when pushed to the limit, and especially little knowledge of what systematic discordances might be found in the work of different observatories. It was hoped that the discussion of the material of these nine days, considerable in itself, but only a small part of the whole, might lead to a preliminary value for the solar parallax, of weight equal to that of the best existing values, and at the same time be some guide in the operations which must eventually be undertaken to combine the whole of the observations in one definite solution.

§ 2. The first step was to choose the stars which were to form the standard comparison stars.

For this system the stars of reference† selected by M. Loewy for special meridian observation are not suitable. They are chosen for plates 2° square, and in great part lie outside the limits of the smaller fields of many photographic telescopes; and they are on the average considerably brighter than the planet. A set of stars was chosen, including a few of these reference stars which lay near the track of the planet, and a number of others which were comparable in brightness with *Eros*, and evenly distributed, so that

* *Monthly Notices*, June, 1904.

† *Étoiles de repère.*

one might count on getting at least ten suitably distributed stars in any field with a radius of 15′. Photographic copies of a chart of these stars were sent to all the observatories who had photographs within the selected dates, with the request that in measuring their plates they should select from the list about ten stars, with the planet near the centre of gravity of the group, and should send to Cambridge a copy of the measured rectangular co-ordinates of stars and planet, uncorrected for anything except errors of the measuring machine and réseau.

§ 3. I must make grateful acknowledgement of the kindness with which this request was received. The directors of eight observatories have done me the honor of placing in my hands measures made under their direction, fulfilling in somewhat various ways the proposed conditions.

It will be generally convenient in what follows if each separate set of measures as communicated to me is called a plate, though in most cases a number of exposures were actually made on the same plate. The contributions were as follows:—

Algiers	measures of	40	plates
Lick	"	28	
Minneapolis	"	17	
Northfield	"	23	
Oxford (University Obs.)	"	32	
Paris	"	21	(means of 3)
San Fernando	"	9	
Tacubaya	"	15	
These, added to			
Cambridge	"	110	

make up the total of 295 discussed in the present paper.

Some more Oxford plates arrived unfortunately just too late to be included.

Each Paris plate is the mean of three separate exposures. On it are measured, in accordance with the Paris programme, all the stars of reference, and all the stars lying in a square of 20′ with the planet at its centre. A number of my standard comparison stars are found in this square, and some others are among the fainter reference stars. The average number of standard comparison stars on the Paris plates was 14.5.

The Algiers plates are measured on the same plan, but the exposures are single. The number of standard comparison stars measured on the Algiers plates was on the average 12.

On the San Fernando plates all the reference stars and all the stars in my list were measured. On the Tacubaya plates a large number of the stars in my list were measured. On the Lick, Minneapolis, Northfield, Oxford, and Cambridge plates groups of about ten stars were chosen from this list and measured.

The Algiers, Paris, and San Fernando plates are impressed with a réseau, but measured in millimetres; the Oxford, Cambridge, and Tacubaya plates are measured in réseau intervals (5mm.); the Lick, Minneapolis, and Northfield plates are measured in millimeters without a réseau. The Tacubaya plates were measured by estimation on an eyepiece scale, and the results will be comparatively rough.

§ 4. *Standard Centre.*—A feature of the method to be used is the transformation of every plate to the standard centre and standard axes of rectangular co-ordinates. The standard centre used in the experimental reductions was in R.A. $1^h\ 57^m\ 8^s{\cdot}0$, Decl. $+\ 04°\ 22'\ 0''$ (1900.0), and it has been found convenient to retain this throughout. The standard axes in the tangent plane to the sphere at this point are respectively at right angles to and along the projection of the meridian through the standard centre.

§ 5. *Construction of the Standard System of Comparison Stars.*—In the Paris circulars Nos. 8 and 9 the results of the meridian observations of the reference stars made at a number of observatories are given in the form of a table of mean places found by each observatory. As the number of observations at different observatories varied very much it seemed well to weight the results by the square root of the number of observations on which each depends.

It should be noticed that the system of weights adopted is by no means unimportant. I have remarked in the *Observatory* (vol. xxvi. p. 342) that the final places of the reference stars adopted at Bordeaux, Paris, and Cambridge differ systematically from one another, and that in consequence *absolute* places determined by these three observatories would not be homogeneous, and could not properly be used as they stand in a determination of the solar parallax. As, however, I have ventured to contend that it is a mistake to attempt to deduce absolute places of the planet for use in the parallax equations, and shall throughout this paper consider the deduced places of the planet as relative only to my adopted system of stars, it is not necessary to insist further on this point.

Rectangular co-ordinates for the standard centre and axes were calculated from the adopted places of the reference stars for

1900.0, and these will, as usual, be called standard co-ordinates.

The places of the standard comparison stars were obtained from Paris and Cambridge plates. The Paris plates contained a number of the standard stars in the 20′ square; and a set of Cambridge plates was specially measured with all the available reference stars. These measures, referred to many different centres, were all transformed approximately to the standard centre and axes by the method given in § 8.

The six constants of the ordinary linear reduction were determined from the reference stars on each selected Paris and Cambridge plate, and the comparison stars were thus reduced to standard. On collecting the results it appeared that the places deduced from the two series of plates agreed fairly well with one another. The Cambridge x co-ordinates averaged 0″.1 greater than the corresponding places, which is probably an effect of the nature of magnitude equation due to the fact that the Paris plates were reduced with many more bright reference stars than the Cambridge plates; it has been shown that there is a sensible magnitude equation in the meridian places (F. Cohn, *A. N.* 3952). But when the differences Cambridge minus Paris were classified with respect to magnitude there was little if any trace of relative magnitude equation between the two. It is possible, therefore, that the zero of the adopted places of the standard stars, the simple mean of all the individual results, may be affected by magnitude equation, but the internal smoothness of the system is unaffected by it. The number of places included in each mean averaged 6.5. It was estimated that the probable divergence of any adopted place from a smooth system (not necessarily from its absolute place) would be less than 0″.1; and it will be shown later that the internal errors of the system are actually a good deal smaller than was estimated (see § 10).

The resulting catalogue of standard places of forty-eight comparison stars has served for the complete reduction to standard of all the plates (with the exception of one series which will be mentioned later).

§ 6. *Choice of Scale Unit and Reduction to Scale.*—The greater part of the measures sent to me were expressed in millimetres on the plate, the remainder in terms of the 5 mm. réseau. As the focal lengths of the telescopes employed varied from nine to twenty feet it was necessary to adopt some standard scale to which everything should be reduced. As proposed in the second paper, I have converted all the measures into a scale whose unit is the one-thousandth part of the focal length of the telescopes

employed respectively in making the photographs. One unit in the fourth place of decimals is then very nearly 0″.02; the probable error of a single measure on the best plates is about three times this quantity, so that my unit is just about the right size to give a suitable degree of accuracy in the computations, without any superfluous figures, if the reductions of the stars are carried out to four places of decimals, and the reductions of the measures of the planet only to five.

The first step in the treatment of all the measures was to reduce them approximately to this standard scale of one-thousandth the radius of projection. by multiplication on the arithmometer.

§ 7. *Second Order Terms in the Differential Refraction.*—The next step was to apply to the measures such part of the correction for differential refraction as involves the squares of the co-ordinates on the plate. These corrections rarely amount to more than a few units in the fourth place; but since they consist of the sum of six small terms they are troublesome to compute. To save this labor I have devised a graphical method of determining them, which is described in *Monthly Notices*, lxiii. 138, 1903 Jan. This method has been used throughout, and has been found very convenient.

§ 8. *Transformation to the Standard Centre.*—The next step is to transform the measured co-ordinates to the standard centre.

Let the R. A. and Decl. of the original centre of the plate be A_1, D_1; and of the standard centre be A_2, D_2; and let $A_2 - A_1 = a$

Then if x_1, y_1 be the measured co-ordinates of a star, x_2, y_2 those co-ordinates transformed to the standard centre, it is easy to show that

$$x_2 = [x_1 . \cos a + y_1 . \sin D_1 \sin a - \cos D_1 \sin a] / N$$

$$y_2 = [- x_1 . \sin D_2 \sin a + y_1 (\cos D_1 \cos D_2 + \sin D_1 \sin D_2 \cos a) + \sin D_1 \cos D_2 - \cos D_1 \sin D_2 \cos a] / N$$

where the denominator N is equal to

$$x_1 . \cos D_2 \sin a + y_1 (\cos D_1 \sin D_2 - \cos D_2 \sin D_1 \cos a) + \sin D_1 \sin D_2 + \cos D_1 \cos D_2 \cos a$$

A rigorous transformation by these formulæ is exceedingly cumbersome; it is, however, unnecessary. The transformation differs from a linear transformation owing to the presence of the denominator, and consequent introduction of terms of the second order in x_1 and y_1. But when the distance between centres amounts to only a few degrees these terms are small; and when the distance is only a few minutes they are negligible.

Consider the following equations:

$$Mx_2 = (x_1 + By_1 + C)\ (1 - Kx_1 - Ly_1)$$
$$My_2 = (-Bx_1 + y_1 + D)\ (1 - Kx_1 - Ly_1)$$

where $B = \sin D_2 \sin \alpha$.

C and D are approximate mean values of $x_2 - x_1$ and $y_2 - y_1$, obtained by inspection of the measured and standard co-ordinates.

$$K = \cos D_2 \sin \alpha / M.$$
$$L = (\cos D_1 \sin D_2 - \sin D_1 \cos D_2 \cos \alpha) / M$$

and $M = \sin D_1 \sin D_2 + \cos D_1 \cos D_2 \cos \alpha$.

For a range of centering such as I have used M never differs from unity by more than 0.0005. We can neglect it in the calculation of K and L, and need not trouble to multiply x_2 and y_2 by it, since the small change of scale value introduced will be eliminated in the further reductions. The numerators differ slightly from the rigorous expressions, but are sufficiently close to it to give the terms of the second order. If, therefore, we transform by these approximate relations, omitting M, instead of by the exact expressions given before, we introduce the second order terms accurately, but leave outstanding some not very large terms of the first order, which are included in the linear reduction which follows.

When our unit is the one-thousandth of the radius of projection, and $D_2 = 54° 22'$, we have

$$B = \alpha \times 0.000\,236$$
$$K = \alpha \times 0.000\,000\,169$$
$$L = (D_2 - D_1)' \times 0.000\,000\,291 + \alpha^2 \times 0.000\,000\,000\,020,$$

where α is $(A_2 - A_1)$ expressed in minutes of arc, and K, L have been adjusted to the unit in which the x's and y's are expressed.

This method of approximate transformation of centres has been used throughout, and has proved very simple and convenient. When the plates are in pairs—that is, two exposures close together on one actual plate—these computations are easily checked by differencing.

§ 9. *Reduction to Standard.*—The six constants of the linear formulæ for reduction to standard were determined for each plate in the usual way by the method proposed by Dyson. When there are many plates with the same group of comparison stars it saves work to invert the process and reduce standard to ob-

served; only the numerical terms are then different from plate to plate. Afterwards the constants thus found must be reversed, and when their values are large the reversal involves a little more than mere change of sign. It is easily shown that if a, b, c, d, e, f are the constants for reduction of standard to observed, and A, B, C, D, E, F the constants for reduction of observed to standard, then

$$\begin{aligned} A &= -a + a^2 + bd & D &= -d + ad + de \\ B &= -b + ab + be & E &= -e + bd + e^2 \\ C &= -c + ac + bf & F &= -f + cd + ef \end{aligned}$$

These expressions are used in a paper by the author in the *Astronomical Journal*, No. 475 (vol. xx. p. 151); but it should be noted that a misprint occurs there of c for e in two places.

All the comparison stars as well as the planet have been reduced to standard, and the residuals formed from the adopted standard places. The condition that the sum of the residuals in each co-ordinate should be zero is a valuable final check on a reduction of which the greater part has already automatically checked itself.

§ 10. *Accuracy of the Adopted Standard System of Comparison Stars.*—The residuals in the reduction of each star, in the sense standard minus observed, may be considered as apparent corrections to the adopted standard places. They have been collected from the Cambridge, Lick, and Paris reduction sheets, and an apparent mean correction formed for each star that had been used more than six times. The mean of all, without regard to sign, was

$0''.04$ in x $\qquad$ $0''.05$ in y

Of course these individual apparent corrections are really corrections relative to the mean of the group of about ten stars used in the reduction of the plate, so that they will average a little less than the corrections relative to the mean of the whole system. But the groups are thoroughly interwoven and overlapped, and the uniform character of the residuals is a sufficient guarantee against any sudden discontinuities in the system, which alone could do serious harm.

Moreover the residuals used in the above discussion are not altogether free from the effects of certain systematic errors which will be discussed later, and whose elimination would have some tendency to reduce discordances. I think that we may conclude that the P.E. of an adopted standard place is at least as small as $\pm\ 0''.04$, and that the effect of errors in the standard places on the resulting places of the planet will be very small.

§ 11. *Examination of the Series of Photographs for Systematic Error.*—If it had been possible for each observatory to secure observations of *Eros* symmetrically disposed with regard to the meridian there would have been comparatively little reason to fear that systematic errors running through a series of photographs would prejudicially affect the value of the solar parallax deduced from them. But it was actually the case that bad weather made large and unsymmetrical gaps in the work of all observatories. Moreover some observatories have a large preponderance of evening observations in the days about opposition, and all have of necessity a great excess of post-meridian observations throughout the period some weeks after opposition, when the planet was nearest and its parallax greatest. This inevitable dissymmetry gives every opportunity to systematic errors to exert a baneful effect, and it seems to me not possible to accept as axiomatic the statement, which has been made more than once, that they may be trusted to eliminate one another completely in the combination of a large series of observations. On the contrary, two of the series of photographs which we shall have to discuss contain systematic errors so large that they would ruin any determination of the solar parallax into which they were introduced. The errors can, however, be detected by an examination of the residuals in the comparison star reductions. Our next step will be to show that a critical examination of the residuals in each series of plates must be made an essential part of any discussion of the solar parallax from photographs.

It will be convenient to summarize the kinds of error to which attention has at various times been directed.

Errors of Measurement.—All experience goes to show that these are relatively unimportant. The Cambridge machine has no sensible errors of scale or screw, and it will be shown later that the réseau is nearly perfect. The evidence for freedom from error of other machines whose results enter here is not complete, but it may be assumed that there are no large errors. There seems good reason to believe that personality in measurement is very nearly eliminated by reversal of the plate, which has been done in all series except one.

Real Errors of the Image.—A large part of the error in a measured co-ordinate is due to real error in the position of the image. Evidence is accumulating that a set of images close together may be affected by a quite large common error, which is probably local distortion of the gelatine film within the réseau

square. When no réseau is used this error may of course be much greater.

Constant Optical Distortion of the field may be expected in reflector photographs, but not otherwise. There seems good reason to suppose *a priori* that it should be symmetrical about the centre of the field, but it will evidently depend very much upon the brightness of the stars.

Hour-angle error.—Under this name Kapteyn conveniently includes the effect of atmospheric dispersion, and also optical distortions and tilt of plate, varying with the hour angle, due to flexure of objectives, mirrors, and mountings.

Magnitude Equation and Guiding Error.—If the driving is not perfect, but there is a tendency to accumulate error in one direction until it is corrected by hand or automatic control, the brighter stars may be displaced relatively to the faint, and show a kind of magnitude equation varying from plate to plate, but on any one plate depending on the magnitude of the star alone. This is probably one of the most important and subtle errors of the photographic method. It is distinguished from other kinds of magnitude equation, due to an imperfectly symmetrical diffraction pattern of the image, or to personality of measurement, by the fact that its appearance will be capricious.

We shall have occasion to deal with most of these sources of error in the discussion that follows.

A. *The Lick Plates.*—The Lick plates were taken with the Crossley reflector of 36-inch aperture and 17.6 feet focal length, with short exposures averaging 15^s. They were measured on the Repsold machine at Columbia University Observatory, N. Y. Upon reduction to standard the comparison stars on many of the plates had unduly large residuals, amounting in some cases to a second of arc. There was plenty of evidence from other sources that the standard places were of a high order of accuracy, and it became clear that the error was to be found in the plates or the measures. It was chiefly in the x co-ordinates, appearing in this way. The x residuals, in the sense adopted standard minus reduced measure, were positive for stars near the middle region in x, and negative for stars towards both sides, the sum of the residuals being necessarily zero. This arrangement of signs indicated an apparent bodily displacement of the central images relative to the outer, and there was consequently every reason to fear that the positions of the planet deduced from the plates might be systematically wrong. The effect was not constant; on a few plates it seemed to be absent, and in one

or two cases changed sign. It had no apparent relation to the hour angle; was almost exactly the same for a pair of exposures on the same plate, but varied capriciously from plate to plate.

In general character it resembled the effect of a tilt of the plate relative to the optical axis, such as might be caused by an error in squaring on the plate, or by defective collimation of the mirrors. But it needed only a small computation of the amount of tilt required to explain the magnitude of the error, to show that this explanation was grotesque: a tilt of several degrees is entirely out of the question.

The asymmetry of the error with respect to the centre seemed to make it improbable that it was due to optical distortion.

In order to elucidate this perplexing question the Director of the Columbia University Observatory very kindly had measures made of a large number of stars on certain overlapping plates, and the reduction of these confirmed the reality of the error without throwing any light on its cause. I then asked Professor Campbell to be so good as to let me examine some of the plates at Cambridge, and he very kindly sent me three of them. Inspection showed that there was no possibility of a large tilt of the plate; the optical centre was strongly marked by the perfection of the images around it and their regular degradation as they departed from it. It appeared to me, however, that many stars had been measured which I should myself have judged unfit for measurement on account of the familiar umbrella-shaped character of the images, so I decided to try rejecting all the measures of stars more than 20 mm. or 13′ from the centre—that is to say, all stars whose discs were not sensibly round. The effect of doing so was remarkable. When a new solution was made with the stars that were left the residuals were quite small, and the resulting place of the planet was very much altered; and when the outer rejected stars were reduced to standard with the constants derived from the inner stars they gave residuals up to 1″.5.

It is clear that the error was due to the use of stars too far from the centre, and that it is unsafe to measure the Crossley plates where the star discs are not sensibly round. But it remains a mystery why the error should take the shape it does. The images are distorted quite symmetrically with respect to the centre, and there seems no reason why the observer should make an error of measurement always more or less in the same direction on images oppositely distorted. I have tried to go further into this matter, and to discover something more definite about

the law of the error, but have failed. This is, perhaps, not surprising when one considers that the shape of the distorted image depends very much on the magnitude of the star as well as on its position. It is unlikely that one will ever be able in such a complicated case to devise a system of corrections applicable to measures of distorted discs, and the safe course will be to confine measurements of these plates to a field of about 12′ radius, within which the images are small and beautifully defined.

The places of *Eros* to be used in the present reductions depend entirely on these central stars.

B. *Algiers Plates.*—A very puzzling error exists in the Algiers plates, which are taken with the standard Astrographic Refractor. I had hoped to be able to use the Algiers measures in forming the system of standard stars, for many of those stars were to be found in the 20′ square about the planet. But when they were reduced to standard with the aid of the reference stars in the usual way they were systematically discordant from the results of the Cambridge and Paris plates, and could not be used.

At first sight the error looked like a magnitude equation making the x's of faint stars too large; but I am now convinced that magnitude equation is not the chief error. It would be hard to go into details without taking up too much space; the question is much complicated by the fact that the stars measured near the center of the plate are mostly faint, and the stars further out most of them brighter; they give respectively negative and positive residuals. To examine this question properly, it would be necessary to measure both bright and faint stars distributed uniformly over the plate. But I have found as a rule that a bright star among faint ones near the centre gives a negative residual very much like theirs, while a faint reference star far out gives a positive residual as large as that for neighboring brighter stars. Further, if very few stars in the center of the field have been measured at all, the residuals immediately become small, and there is no marked magnitude equation between bright and faint outer stars. The conclusion seems to be that the central stars are displaced upon the plate, not because they are faint, but because they are central; and it was entirely consistent with this to find that Algiers places of the planet differed systematically from the Paris and Cambridge places by quantities of the order of half a second of arc.

This is very remarkable. One is accustomed to expect certain difficulties with a reflector; but it is disquieting to find that a standard astrographic refractor, when devoted to solar

parallax work after long use on the astrographic chart and catalogue, can give results which are wrong by amounts quite serious when judged from the standard of the catalogue, and hopeless as they stand for parallax work. It is not easy to imagine what may be the cause. We cannot suppose that the plates were tilted enough to explain it, and we have not material enough to find a general expression of the second degree to represent it.

It is hard to decide what to do in a case like this. If the error is like the error in the Lick plates, and develops suddenly as one gets away from the centre, it is probably safe to rely on the central stars to give a good reduction. This appears to be the case. Having decided to reject altogether the stars outside the 20′ square, I chose some additional standard stars, and got their places as before, measured them on the Algiers plates, and so had always at least six stars for the reduction, except in a few cases where scarcely any central stars appeared on the plates; these were rejected.

The new places of the plant differed from the old by amounts up to 0″.65 and averaging 0″.48. They seemed to fit the ephemeris very well. But it must be admitted that this is our only ground for assuming that the error for whose existence we can assign no reasonable cause has been altogether eliminated.

C. *Cambridge Plates. Search for Réseau Errors.*—On the Cambridge plates the planet is not always referred to precisely the same réseau line, whose error, if any, might appear to give a uniform correction to the place; nor is it referred to so many different lines that accidental errors might be expected to go out in the long run. The réseau must, therefore, be examined. Several published investigations of Gautier réseaux show that the errors of the réseaux themselves are very small, of the order of the division errors in the best divided scales. But it has recently been shown by Ludendorf (*A. N.* 3746) and Bohlin (*Astr. Iakktagelser*, Stockholm, Bd. 6, No. 5) that a réseau perfect in itself may produce imperfect copies through what is known as projection error. It seems that something—probably the fine cut in the glass made by the diamond point that cuts away the silver—may deviate the light just as it passes through the réseau, and produce errors in the copy much larger than in the original. If we determine the errors of the original we must also determine the projection errors, and both are difficult and troublesome matters. We may, on the other hand, achieve our end, which is to find the errors of the photographic copy (apart from

gelatine distortion), by examining plates impressed with a réseau to a number sufficiently large to eliminate the gelatine distortion, provided that this may be treated as accidental, and vanishing in the mean of a large number of plates. The supposition is most likely correct for the central portions, and incorrect for the edges of the plate; it will serve our present purpose.

I am indebted to Mr. Russell for the use of a strip of photographed réseau, of which he has determined the errors, so that it can be used as a standard scale. This was superposed on several plates, parallel to the X axis, so as to almost coincide with the réseau lines at the points from which the x co-ordinates of the planet are measured. The distances between eight or ten réseau lines on these plates and adjacent lines of the standard scale were measured, the corrections for errors of the scale were applied, and the resulting apparent errors of the photographed réseau in sixteen strips altogether were plotted. The results are briefly as follows:

The apparent errors of successive lines deviate from a smooth and nearly straight line by quantities averaging about 0.001 mm., equivalent to 0″.035 on my plates; a considerable part of this deviation must be accidental error of measurement. The errors of two points of a line not more than 1 mm. apart are frequently of opposite sign—that is, the line images are a little rough. When means are taken the deviations of the apparent mean errors from uniformity are almost within the limits of probable accidental error. The conclusion is that there is practically no evidence of sensible error in the photographed copies of the réseau, apart from the general smooth distortions of the gelatine film which the use of the réseau eliminates. In one case only did an error amount to 0.005 mm., and at that point the réseau line was obviously defective; the defect had been noted when the plate was measured, and special precautions taken to avoid it.

Search for Hour Angle Error.—It is clear that errors of this category can produce no resulting error in the place of the planet unless they are differential, varying from star to star on the plate. If they are due to dispersion they will bear a definite relation to the projected position of the zenith on the plate. If they are due to variable distortion they will probably at least change continuously with the hour angle. In looking for them I plotted the apparent correction to the adopted place of each comparison star deduced from thirteen groups of four exposures each; and alongside them the relative positions of the projected zenith.

There was no relation to the zenith; nor was there continuity of any kind in the group displacements. I conclude that there is no sign of dispersion or of any differential distortion in the stars on the Cambridge plates. That does not prove that there is no dispersion effect on the planet, but it renders it more unlikely, since there is some experimental evidence to show that the effective wave-length of the planet's light is in no way abnormal (Prosper Henry, *Paris Circular*, No. 8, p. 41).

Guiding Error.—In searching for guiding error one naturally looks for large residuals for the few bright stars, balanced by smaller residuals of opposite sign for the more numerous faint stars. It must, however, be borne in mind that an uneven distribution of the bright stars may to a large extent mask this effect. If we have two or three bright stars at one edge of the group, and no accompanying faint stars, the linear reduction may strain the fit to suit these bright stars at the edge, and leave them with small residuals. The existence of large residuals for certain bright stars, especially if near the centre, is therefore an indication of guiding error which is not necessarily contradicted by the fact that certain other bright stars have not large residuals of the same sign.

On examinations of the residuals for the Cambridge plates I was struck with the fact that the average residual of two bright central stars was large on twelve consecutive plates (1900 November 10), while the residuals for two bright stars at the edge of the group were small. This looked like a case of guiding error, and I was fortunately able to make a more than usually conclusive test. My earlier experimental reduction of this plate depended on faint stars. A comparison of the numerical terms in the equations of condition of this first reduction with the corresponding terms in the present solution ought to show, perhaps, a steadily increasing difference, but no irregularities. This was so, except for the twelve exposures under suspicion, which showed marked divergences of about 0″.2, and strengthened the idea that the bright stars were in error and spoiling the reduction. I therefore rejected these four stars and used four fainter, making a new solution which gave decidedly different values of the constants, and altered the place of the planet by about 0″.1 on an average.

No other plates show signs of guiding error comparable with this found on the bad set of twelve consecutive plates, which may perhaps be attributed to some temporary derangement of the automatic control. But the possibility of so large an error

affecting a series of exposures with large parallax factors of the same sign is one that must be reckoned with, and seems to me a most powerful argument for the necessity of examining the residuals of all the comparison stars on every plate.

D. *San Fernando Plates.*—The result of the reduction of the San Fernando plates is disappointing. Admiral Viniegra very kindly had measured for me the places of all my selected comparison stars, in order to give additional material for the formation of my standard system; but when the reductions were made the results differed so largely and irregularly from the accordant results of Paris and Cambridge that it seemed unwise to use them in the formation of the standard system. On inquiry I learned that the plates had been measured in only one orientation. This fact compels me, very regretfully, to exclude the San Fernando results from my solution.

E. *Northfield Plates.*—A good many of the Northfield plates were taken on a plan which, one may venture to say, is certainly unsatisfactory. The guiding star was placed successively on the four corners of a square reticle, and then once more on the first corner. The motion of *Eros* in the interval was sufficient to clear the images of the planet, but the stars in the first corner exposures are superposed and measured as one set. Apart from the fact that the fit of the two sets of star images cannot be perfect, owing to changes in the differential refraction, orientation due to maladjustment of polar axis, etc., there are grave reasons for fearing guiding error when two exposures are superposed with an accuracy limited by the accuracy of pointing with a not very powerful guiding telescope. I think that there can be no doubt that the comparative roughness of the Northfield results is partly due to this procedure. An examination of the comparison star residuals does not, however, show any signs of systematic error on the plates.

F. *Minneapolis Plates.*—An examination of the residuals in the reduction of the comparison stars to standard showed an error which is probably due to some kind of optical distortion. The measurers' notes contain references to elongated and winged images, and it is clear from the Lick results that these must be treated with caution. I should have tried to treat these plates in the same way that the Lick plates were treated had it not been for the fact that on many Minneapolis plates the images of the planet are far from the centre of the plate, and the group of comparison stars is in consequence very unsymmetrically placed upon it. As an experiment I have made new solutions after re-

jecting the outer stars of the originally selected groups, and have obtained new places of the planet differing systematically from the old. But, owing to the want of symmetry, there does not seem to be any guarantee that these new places are clear of error; and the danger of using them is aggravated by the fact that the parallax factors for the Minneapolis plates are nearly all of one sign. On taking all these things into account I was very reluctantly compelled to decide that it would be safer to leave out the Minneapolis results from my solution.

The Minneapolis plates also suffer from the fact that a good many of the exposures on the stars are multiple, made at intervals great enough to allow the images of the moving planet to clear one another. The roughness of the accordance between the resulting places of the planet and the ephemeris confirms the impression derived from the Northfield plates that this is a method of procedure which should not be employed again.

G. *Oxford Plates.*—On one of the Oxford plates there is a clear case of guiding error running almost uniformly through half a dozen exposures. It has been treated in the same way as the like Cambridge case, by rejecting the bright stars and solving afresh.

H. *Paris Plates.*—No case of abnormality or suspicion of systematic error has arisen in the examination of the Paris star residuals.

(TO BE CONCLUDED.)

A THREE-INCH TELESCOPE FOR THE HIGH SCHOOL.

Wm. W. PAYNE.

Since the question of teaching the elements of Astronomy in the public high school has been under discussion in this magazine, we have received a number of letters from persons in different parts of the United States, urging us to continue the work so favorably begun, and to bring it definitely to the attention of superintendents and science teachers in the high school so that they may clearly understand the advantages to be derived from introducing elementary astronomy into the high school course, and may have knowledge of some of the more modern ways of giving instruction in this branch of study, by what may be given in this publication, and in other ways that may be accessible to those in want of such information.

It is gratifying and encouraging to know that some of the superintendents of the high schools in Minnesota have been con-

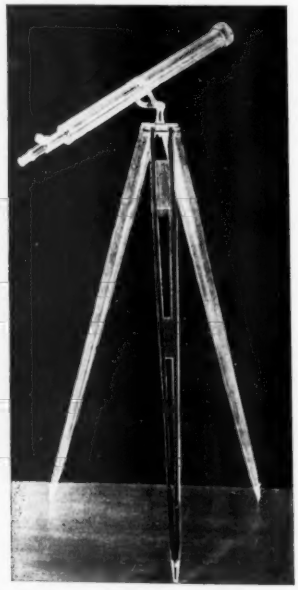
sidering this matter very thoroughly, and have written about it very pointedly and very intelligently. Professors in some academies, colleges and universities have done the same. The positions taken by these teachers and school officers have been so strong and so urgent, that it has seemed wise to us to try and help so worthy a cause more in the future than we have been able to do in the past, especially since we know of this general interest and that persons so interested stand in the front rank of educational work at the present time.

In looking into this matter carefully, it has seemed to us that the first thing to do was to secure a good telescope that would be especially adapted to high school uses, and still be within the reach of most high schools so far as the price of the instrument is concerned. There is a very delicate and important point in the plan to be unfolded. The optical work must be perfect, the mounting should be strong and light and convenient in form for ready and safe handling. The clear aperture of the object glass should be at least three inches in diameter and there should be three direct eye-pieces varying in power from about 25 diameters to 150. The plan of the mounting and the work in detail should be the best that responsible and reputable makers can devise and execute. After discussing this problem with some of the best practical opticians and makers of the mountings of telescopes, with the wants of this class of schools in mind, we will give, somewhat in detail, the results of these conferences.

In order to test the opinions of some of the well-known makers of telescopes, and to compare their claims carefully with our own tests, we asked that a sample telescope of this kind be made for us especially, that we might examine it thoroughly so that we might inform all persons interested in such an instrument, about its workmanship, and just what it would show in the study of the heavenly bodies. We asked that the object glass be three inches, clear aperture, in a brass tube, finely laquered, and mounted in alt-azimuth fashion, on a tripod whose legs are about six feet long. Considerable more of detail was considered regarding the quality and finish of such an instrument, its cost, and its care that need not be specified at this time, but which will be spoken of later in another connection.

In a short time after the above order was given, the telescope was completed and shipped to Northfield, but it came during the two months of absence in the Rocky Mountains, so that an examination of it was necessarily deferred until last month after our return from the West.

That our readers may see how the telescope looks, I asked Dr. Wilson to take a photograph of it, and the accompanying cut has been made from the photograph secured by him for this purpose.



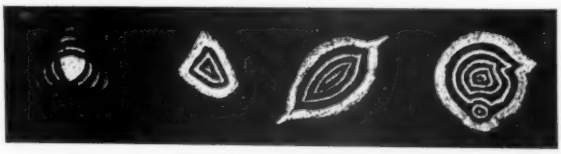
Our readers will please notice that the tripod is made long so that it may stand high when direct eye-pieces are used, for the convenience of the observer. Most telescopes of this size in general use have such low and light mountings, that much of the advantage of using them is lost, because of the awkward, uncomfortable and unsteady position that the observer must be in, much of the time, to use them. Very often, too, small telescopes of commercial make have such small and light mountings as to make them very unsteady if they are in use when wind is blowing even lightly. A mounting intended to be used on a table is in no way desirable. It will be a great mistake to try to use a three-inch instrument in that way. While the mounting of this sample telescope looks high and light for so small an instrument, it is found to be very steady because the legs of the tripod are made of oak, in divided form, and securely stayed with two blocks of oak, for each, for strength and lightness and to avoid wind tremors as much as possible in open air use. Though not

shown in this cut, the instrument is provided with a plain box for the telescope and the three direct eye-pieces, so that the optical parts when not in use may be kept from dust and needless handling. How to care for the object-glass and eye pieces of a telescope will be spoken of later. When a new telescope is to be used for the first time, or by one not accustomed to such work, especial care should be exercised that none of the parts be injured in setting it up and in making trial of it.

Usually makers are careful in packing instruments which are to be shipped to any considerable distance, and the chances are very few that they will be harmed at all in transit to the purchasers.

When the new telescope is ready for use an inexperienced observer can very soon tell for himself if the telescope works well. Try an easy object like the Moon, Jupiter, Saturn or any one of the bright stars. Any one can readily tell if the images are sharp and distinct in the central part of the field. By moving the eye-piece in or out from the true focal plane a little attention to the images so formed will give information how well the maker has succeeded in finishing the glasses in the objective in regard to proper curvature and color-correction. We give below some illustrations suggested by E. Walter Maunder of England, in *Knowledge Diary and Hand-book*, for 1904, indicating fairly well how object-glasses form images, if perfect or imperfect, and what the defects are in either case. The figures from 2 to 7 show the appear-

FIG. 2.—Appearances observed when objective is out of quare.



a. b. c. d.

FIG. 3.—Diagrams showing effects due to (a) flexure; (b and c) strain in cell; (d) veins on objective.

ances of the image of a bright star in good eye-pieces, when thrown out of focus. Figures 2 to 6 show the appearances seen under different conditions of defect or faulty adjustment of the object-glass. Figure 7, those seen when a perfect objective is in complete

adjustment, showing the ring system belonging to the spurious image of a star so-called. Inexperienced observers must not

FIG. 4.—Appearances due to spherical aberration.

expect to see actual star images as strongly marked in ring effect as the last figure shows. The seeing must be very good

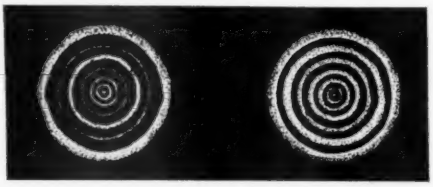
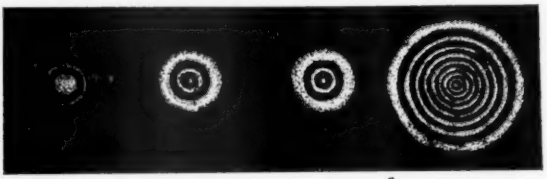


FIG. 5.—Appearances due to zonal aberration.

and the telescope quite perfect to get the diffraction rings plainly. The other figures produced from the conditions named if such

FIG. 6.—Elliptic rings produced by astigmatism.

exist will be easily seen and readily noticed by one having little experience, if the attention is once called to it.



a. b. c. d.

FIG. 7.—Diagram showing spurious disc and refraction rings seen with a perfect objective, (a) in focus; (b) a little within the focus; (c) a little outside the focus; (d) far from the focus.

September 21, about noon, the new telescope was turned on the Sun, and the image thrown out of focus and projected on a piece of white card-board, using each of the three powers 25, 50, 150. The seeing was about six on a scale of ten; sky was milky and the wind was blowing from the east at a rate of about ten miles per hour. The image of the Sun was clearly defined, the limb showing the brown border, for about one-fourth of the radius, due to absorption. The even and gradual fading out of this darkening of the limb, as the eye passed inward, toward the center made a fine picture of symmetry that was very satisfactory. One small spot was in view, but it was too small for detailed observation. The seeing was not good enough to show the granular structure, or the faculæ, if prominent markings of this kind were in view at the time.

On Sept. 20, 8^h, the Moon was observed with all the powers. The seeing at that time was about eight on a scale of ten. In looking at the limb of the Moon for color, but a very thin thread of it could be seen anywhere in the field when the focus at the center of the gibbous Moon was at its best. In this instance the color correction of the lenses in the light of the images seems to be almost entirely free from any noticeable errors. Our readers, doubtless, already know that no telescope maker has yet found a way to construct a refracting instrument whose images should be absolutely free from color. Physicists believe that the difficulty is theoretical, and so impossible of removal until some new and better method has been discovered. Although the Moon is an easy object for a good three-inch telescope, a careful examination of the fine details of the surface will give ample opportunity for testing the definition. We looked at the craters Tycho, Copernicus and Gassendi. The terraces of the inner and outer sides of the walls of these great craters were well seen, the peaks surmounting the walls and the shadows on the floors of the craters were also seen, this being a harder test than the former one. We then tried a study of the floor of Gassendi. We could see that it was uneven and that its central mountain had three peaks, but the seeing was not good enough to show the many rills and craterlets, that possibly might be observed under better conditions, judging from what else was seen, not much more difficult.

Jupiter, which is not a very difficult object for a three-inch telescope, was next observed. Its moons were all in view, and its more prominent belts were easily seen. The detail of the great southern belt was considerable, and, in power 150, gave a very in-

teresting view. The unequal polar and equatorial diameters of the planet were readily detected by the eye, without the aid of measures of any kind.

The planet Saturn was next in view. It was near the meridian and about 5° south-west of the Moon. The ball and ring were fully separated, the middle of the ring is brighter than its inner or outer parts, as it should be. The inner edge shows the strong darkening that belongs to the portion known as the crape ring, but the full width of the part of the ring could not be seen; we did not expect that, for such observation was too hard for a three-inch aperture in such seeing as that evening afforded. We also saw the belts on the disc of the planet, and glimpsed the Cassini division of the rings at the right ansæ. The view of Saturn was unexpectedly satisfactory.

The view of the bright Vega, (α Lyræ) was taken to see how the star images would look when the eye-pieces were out of focus. That would help us to understand if there were any zones in the objective that were poor in fignre or bad in centering by lack of care on the part of the optician. It is a pleasure to say that no such defects were found, but that the images were like those in Fig. 7 showing the ring system as plainly and as well as could be expected from the seeing at the time. The view of the double star Mizar in Ursa Major was a fine one with the power of 150.

The Mizar components were clean and sharp, and their star colors were perfectly shown, as white and emerald, which is according to the best authority we know of in the star-color work.

The night was not good enough to put the new telescope to the severest tests that it should bear theoretically, and we have not yet been able to do that before this writing which must be completed now for our forthcoming issue. We have only fairly begun to show what a fine three-inch can do, and this work will be continued until those interested in the right kind of telescope for the high school shall become acquainted with knowledge of these things easily within their reach.

It should be stated that the publisher of this magazine has no financial interest in this telescope except that he is the owner of it, having paid $90.00 for it, exactly what any one else could buy it for. He personally knows the makers as well as many others in the United States, some of whom can make just as good a telescope as this one undoubtedly, if they were asked to fill such an order.

The whole object of the writer is to bring to the attention of high school authorities what seems to us, one of the best

branches of study that could be in a high school course, with suggestions how to pursue it most effectively.

PROFESSOR WINCHELL'S NOTES ON A VERY BRILLIANT METEORITE.*

The brilliant meteoric phenomenon which passed from west to the east early last Wednesday morning, July 26, and which was witnessed by a few people in different parts of the state was one of the most brilliant displays of light for a good many years. The young ladies and gentlemen who were guests at Idlewild cottage, had the pleasure of looking upon this awe-inspiring turning of night into day. The young people were returning from New Paynesville, Minnesota, at about 12:30 Wednesday morning when the brilliant meteor passed over the heavens. It lasted a quarter of a minute and during that time the opposite shores of the lake could be seen almost as plain as in broad day. The awful light proved conducive to a good many inward shudders. —Litchfield *Independent*.

Speaking of the search which he himself made, Professor Winchell says:

I started out at once on hearing that the meteorite had been found near Kenyon, although there were statements in the newspaper accounts that were palpably erroneous. Those errors I thought might be due to hurried statements by the reporter augmented by a lively imagination. What was my chagrin on finding that the reporter had made up the whole account from imagination—excepting only that it was true that on the night stated a meteoric disturbance and a loud noise were witnessed in Goodhue county, and that the meteor's streak was seen to the north from Kenyon.

With that as a basis I started across the country northward, calling at the farm where it had been reported that the meteorite

* On the morning of July 26, 1904, a very brilliant, detonating meteorite made its appearance in southern Minnesota. In the vicinity of its path its wonderful display attracted considerable attention, from the few who were fortunate enough to see it, and from the many later who were aware of the near approach of such a dangerous, celestial visitor. Those in charge of this publication were in Montana when this interesting phenomenon occurred, so that no personal attention could be given to it. The management, however, is fortunate in having the aid of Professor N. H. Winchell of Minneapolis, in securing the following facts about this new meteorite. Professor Winchell's great interest in the study of meteorites is well known to scholars in Geology and Astronomy.

had "burned the oak trees." Only stating that there is not an oak tree on that farm, and has not been within the knowledge of the old pioneer who owns it, I would say that I made frequent inquiries along the road toward Holden and Dennison but could get no positive statements until I reached Dennison. This I attributed to the fact that the visitor came in the dead of night and was not heard. At Dennison I was directed to Mr. Kelly, a druggist of Northfield, but found that he knew nothing of the matter. He suggested that Mr. D. A. Kelley, who lives in the south-eastern suburbs of Northfield might be the man meant by the people at Dennison. Arriving at Mr. D. A. Kelley's house I found, agreeably to my surprise, that the ladies, who had happened to be out late that evening, had retained a vivid recollection of the event. Their description was consistent and evidently accurate. There was a stream of light, a rumbling noise and lastly an explosion. It was toward the north-east from them, and seemed not to be far away, but moving to the eastward from them.

The substance of the rest of my trip and search is in the Minneapolis *Journal* extract given below.

"At George Lyman's, about three miles east of Northfield, on the road to Dennison, the description given by Mrs. Lyman indicated that the meteorite must have fallen not far from his farm, perhaps somewhat to the north-east. There was a flash and a terrific explosion, loud as a cannon, but "not like a cannon." The whole family were startled from a sound sleep and rushed from their beds to learn whether the house or the barn had been struck by lightning, but it was at once apparent that no thunder could have made the noise, as the sky was clear and the moon was bright.

Although inquiry was made of several others no definite information could be obtained. It was in the dead of night. If a farmer had heard it or had seen the flash he would probably have turned over in bed, only muttering that another thunder shower had risen to wet his already soaked grain fields.

Judging from all the data, I am convinced therefore that the stone fell inside the triangle formed by lines drawn between Lyman's farm, Dennison and Randolph, and probably not more than two miles from Lyman's. The probability is that it is toward Randolph from Lyman's rather than toward Dennison. The chances are good for finding it. At present the country is covered by standing grain. Soon the fields will be everywhere cut by the reaper. If the farmers will be on the lookout it can hardly escape such a reaping and raking.

In falling the stone must have made some impression on the grain and soil. The former is destroyed by being beaten into the ground over a space say of a square yard, and the latter may show a hole in the ground where the stone struck. The stone may have entered the soil a few inches and be invisible, or it may have bounded out and may lie a few feet from the point of first impact. It was not hot enough to burn anything. When the Winnebago meteorite fell it struck a dry turf on which was some long, dead grass. The stone went into the turf and did not burn the dry grass, as it was found adhering to the stone afterwards, when it was taken out. Another small piece fell on a straw stack and did not fire the straw.

The popular notion that these stones are hot is erroneous. The heat is entirely superficial and vanishes at once. It is caused by the condensation and friction of the air along the path of the stone through the atmosphere, but it does not last long enough to heat the stone within. It is probably this friction also which causes the stone to break, as they usually do, and to cause the loud reports heard near the point of striking the earth. As to the appearance of the stone, it is black and smooth, or brown-black. It is gray within, but owing to the fusion of the outside a thin crust is formed all over it which is nearly black. In case the stone broke into two or more pieces, the surfaces of fracture will show a thin crust, or, perhaps, will be only slightly colored depending on the distance the pieces traveled in the atmosphere after the explosion.

The region is one of original prairie, and has few stones on the upland. Hence the farmer's attention would be attracted at once by the appearance of such a stranger on his field. I would especially urge the drivers of the teams that haul the reapers to be on the watch for any appearance of unusual downthrow of the standing grain, and also to scan carefully any small new hole in the soil which has the appearance of having been made by the descent of this meteorite.

In case the meteorite is found, or in case any one finds a stone that he thinks may be the meteorite, I shall be glad to give any information I can. It is very much to be desired that this third celestial visitor be properly received and cared for.

Planet Notes for November.

H. C. WILSON.

Mercury will be at superior conjunction on the morning of Oct. 31 and will not be easily visible to the naked eye during November. The planet will be at aphelion Nov. 13.

One of our readers has been troubled because he found it difficult to see Mercury at the time of the greatest elongation in August. This was because at that time Mercury was near its greatest distance from the Sun. The orbit of Mercury is quite eccentric so that when the planet is at aphelion it is nearly one and a half times as far from the Sun as it is at aphelion. Since the light received from any source varies inversely with the square of the distance, it follows that Mercury receives less than half as much light from the Sun when at aphelion as when at perihelion.

The brightness of Mercury as seen from the Earth depends upon several variable factors, the more important of which are the angle of elongation from

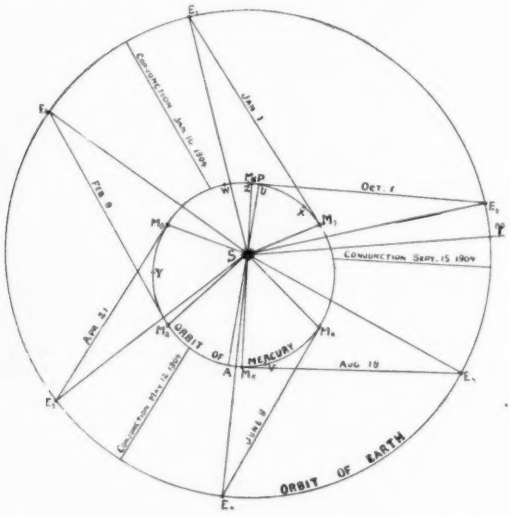
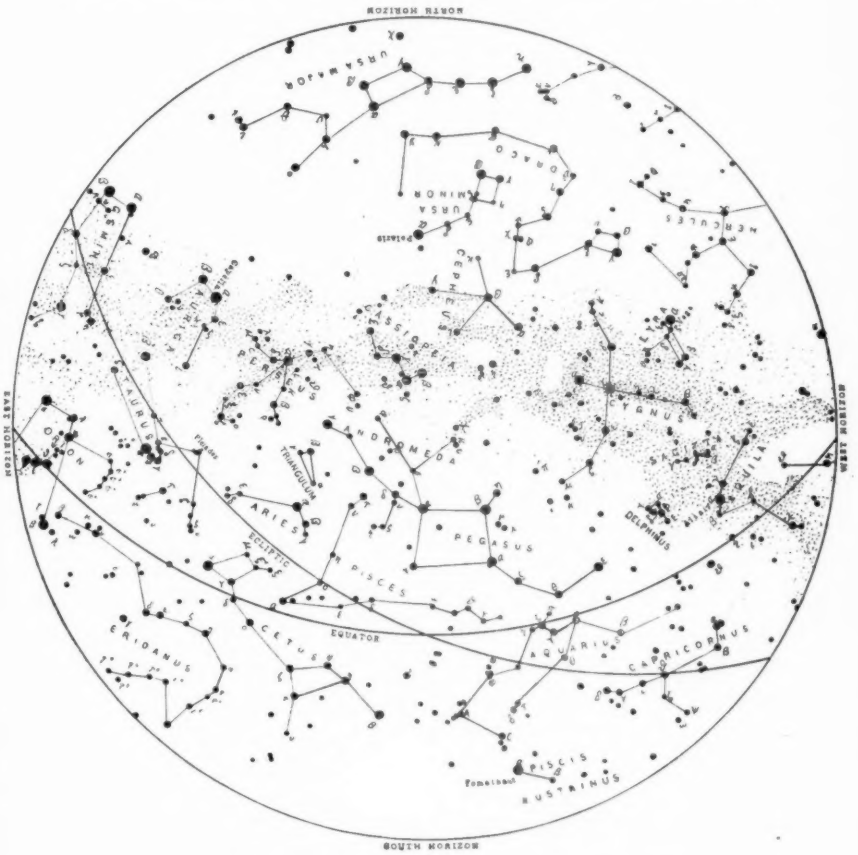


DIAGRAM SHOWING POSITIONS OF MERCURY AT GREATEST ELONGATION DURING 1904.

the Sun, the distance from the Sun, the phase of the planet, and its distance from the Earth. The resultant of all these factors causes the time of maximum brilliancy of Mercury to vary very greatly with reference to the time of conjunction or of greatest elongation. I have tried to place before the eye of the reader, in the accompanying diagram, the relations of these four factors at the different greatest elongations of the planet during this year. The angle at E in each of the six positions of the Earth is the angle of greatest elongation from

the Sun, and the visibility of the planet depends very much upon this. It is usually visible for only a week or two about the time of greatest elongation, because it is then most free from the glare of the Sun and may be seen longer after sunset or before sunrise. The lines $M\,S$ indicate the relative distances of the planet from the Sun and $E\,M$ those from the Earth. The angle between these lines at M in each case will indicate the phase of the planet, the phase being



THE CONSTELLATIONS AT 9 P. M. NOVEMBER 1, 1904.

gibbous when the angle is less than a right angle and crescent when the angle is greater than a right angle. Thus on Jan. 1 the phase was gibbous, 0.59 of the illuminated hemisphere being visible, while on June 8 it was crescent, only 0.37 of the illuminated hemisphere being turned toward the Earth.

In the following table I have put down the numerical values of the several data, taking them from the *American Ephemeris* for 1904. It is possible that

the last figure may be in error by one, since the interpolation was roughly done. In this table E represents the angle of elongation, r the distance of the planet from the Sun in units of the Earth's mean distance, ρ the distance of the planet from the Earth in the same unit, k the ratio of the area of the illuminated portion of the apparent disk to the area of the entire apparent disk regarded as circular, and L the brilliancy of the disk. The unit of L is the amount of light received by an eye from a circular disk with the same reflecting power as the planet, subtending an angular radius of one second of arc, situated at distance unity from the Sun, and illuminated by the latter as the mean disk of the planet is illuminated.

TABLE SHOWING VARIATION IN BRIGHTNESS OF MERCURY AT GREATEST ELONGATIONS IN 1904.

Aspect of Planet.	Washington M. T. 1904		E		r	ρ	k	L
		h	°	′				
Greatest eastern elongation	Jan. 0	13	19	30	0.33	0.99	0.59	60
Greatest brilliancy	Jan. 2	..	..	..	..	..	..	60
Inferior conjunction	Jan. 16	19	..	..	..	..	..	..
Greatest brilliancy	Feb. 1	..	..	..	..	..	..	41
Greatest western elongation	Feb. 9	16	25	52	0.44	0.99	0.50	40
Greatest brilliancy	Apr. 9	..	..	..	..	..	..	70
Greatest eastern elongation	Apr. 21	4	20	12	0.36	0.86	0.42	45
Superior conjunction	May 12	18	..	..	..	..	..	..
Greatest western elongation	June 8	4	23	46	0.42	0.82	0.37	35
Greatest brilliancy	July 4	..	..	..	..	..	..	68
Greatest eastern elongation	Aug. 19	12	27	24	0.47	0.90	0.52	32
Greatest brilliancy	Aug. 24	..	..	..	..	..	..	32
Inferior conjunction	Sept. 15	9	..	..	..	..	..	..
Greatest western elongation	Oct. 1	3	17	54	0.31	0.99	0.51	65
Greatest brilliancy	Oct. 5	..	..	..	..	..	..	66
Greatest eastern elongation	Dec. 13	16	20	30	0.35	1.00	0.62	54
Greatest brilliancy	Dec. 16	..	..	..	..	..	..	57
Inferior conjunction	Dec. 30	22	..	..	..	..	..	..

From this table it will be seen that during this year the brightness of Mercury at greatest eastern elongation ranged from sixty in January to thirty-two in August, and at greatest western elongation from thirty-five in June to sixty-five in October. Also it will appear that the time of maximum brilliancy sometimes precedes and sometimes follows either greatest eastern or greatest western elongation. In January the greatest brilliancy occurred very soon after greatest eastern elongation the planet being at X in the diagram. In February it preceded greatest western elongation by eight days, the planet being at Y. In April on the other hand greatest brilliancy preceded greatest eastern elongation by twelve days, when the planet was at Z, while it followed greatest western elongation in June by nearly a month and in the mean time the planet passed around to U, almost behind the Sun, where it could not be seen.

In August, although Mercury was well out from the Sun and not excessively far from the Earth, and also the phase was just about half full, the brightness of the planet was low because of its relatively great distance from the Sun.

During 1905 the corresponding aspects of the planet will occur about two weeks earlier than in 1904 and so the brightness will not be quite the same. It will, however, be very nearly the same in August.

Venus is evening star, seen toward the south-west soon after sunset. Her brightness will increase from sixty-two to seventy-two during November. The phase of the planet is gibbous decreasing from 0.86 to 0.79 during the month.

The orbit of Venus is so nearly circular that her brilliancy is very nearly the

same at the corresponding aspects of the planet.

Mars is morning star rising in the east between three and four hours before the Sun. The planet is slowly approaching the Earth but is now more than twice as far away as the Sun, so that it is not a very conspicuous star.

Jupiter is near the meridian at ten o'clock in the evening and is between seven and eight degrees north of the equator so that it is in very good position for observation. The four satellites and the more prominent belts of the planet are easily seen with a quite small telescope so that is a favorite object for amateur study.

Saturn will be at quadrature, 90° east from the Sun Nov. 6 and may be conveniently observed on any clear evening in November, the best time being about six o'clock when the planet is not far from the meridian.

Uranus is approaching superior conjunction and so will not be visible during November.

Neptune may be observed after midnight in the constellation Gemini, among the faint stars about 4° east of the star μ.

The Moon.

1904	Phases.	Rises. (Central Standard Time at Northfield. Local Time 13m less.) h m	Sets. h m
Nov. 7	New Moon	6 44 A. M.	5 23 P. M.
14	First Quarter	12 56 P. M.	11 35 "
22-23	Full Moon	4 52 "	7 32 A. M.
29-30	Last Quarter	11 37 P. M.	1 02 P. M.

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
Nov. 4	38 Virginis	6.2	15 26	75	16 10	324	0 44
20	65 Ceti	4.5	3 56	34	4 43	287	0 47
20	25 Arietis	7.3	13 28	58	14 40	269	1 12
23	B.A.C. 1526	5.8	9 03	76	10 17	256	1 14
24	130 Tauri	5.5	6 38	112	7 24	231	0 46
25	W.B. (2) vi, 1630	6.2	16 30	115	17 44	263	1 14
26	B.A.C. 2649	6.3	15 35	102	16 58	284	1 23
26	5 Cancri	6.4	17 31	67	18 29	324	0 58
30	89 Leonis	6.2	12 06	106	12 59	286	0 53

PHENOMENA OF JUPITER'S SATELLITES.

[Central Standard Time].

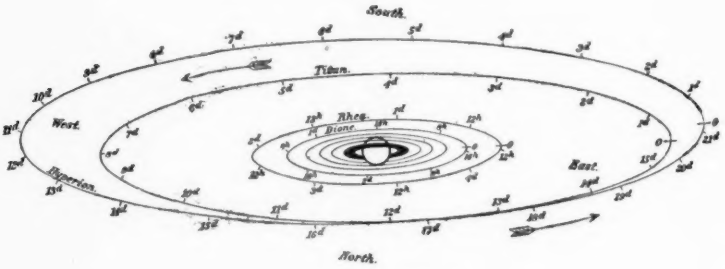
	h m			h m	
Nov. 1	2 59 A. M.	I Tr. In.	Nov. 3	2 05 A. M.	II Ec. Re.
	3 19 "	I Sh. Tr.		2 40 "	III Tr. In.
2	12 13 "	I Oc. Dis.	4	5 35 P. M.	II Tr. In.
	2 46 "	I Ec. Re.		6 02 "	I Tr. Eg.
	9 25 P. M.	I Tr. In.		6 27 "	II Sh. In.
	9 48 "	I Sh. In.		6 30 "	I Sh. Eg.
	10 52 "	II Oc. Dis.		8 00 "	II Tr. Eg.
	11 36 "	I Tr. Eg.		8 57 "	II Sh. Eg.
3	12 01 A. M.	I Sh. Eg.	6	5 54 "	III Oc. Re.

Phenomena of Jupiter's Satellites.—Continued.

	h	m				h	m		
Nov. 6	6	11	P. M.	III Ec. Dis.	Nov. 18	10	11	P. M.	II Tr. In.
	7	56	"	III Ec. Re.		10	19	"	I Sh. Eg.
9	1	58	A. M.	I Oc. Dis.		11	44	"	II Sh. In.
	11	9	P. M.	I Tr. In.	19	12	38	A. M.	II Tr. Eg.
	11	43	"	I Sh. In.		2	14	"	II Sh. Eg.
10	1	07	A. M.	II Oc. Dis.		4	37	P. M.	I Oc. Dis.
	1	21	"	I Tr. Eg.		7	35	"	I Ec. Re.
	1	56	"	I Sh. Eg.	20	4	32	"	II Oc. Dis.
	8	24	P.M.	I Oc. Dis.		4	48	"	I Sh. Eg.
	11	11	"	I Ec. Re.		8	34	"	II Ec. Re.
11	5	35	"	I Tr. In.		10	53	"	III Oc. Dis.
	6	12	"	I Sh. In.	21	12	45	A. M.	III Oc. Re.
	7	47	"	I Tr. Eg.		2	16	"	III Ec. Dis.
	7	52	"	II Tr. In.	24	6	10	P. M.	III Sh. Eg.
	8	24	"	I Sh. Eg.		11	57	"	I Oc. Dis.
	9	06	"	II Sh. In.	25	3	2	A. M.	I Ec. Re.
	10	18	"	II Tr. Eg.		9	07	P. M.	I Tr. In.
	11	35	"	II Sh. Eg.		10	02	"	I Sh. In.
12	5	40	"	I Ec. Re.		11	20	"	I Tr. Eg.
13	5	58	"	II Ec. Re.	26	12	14	A. M.	I Sh. Eg.
	7	31	"	III Oc. Dis.		12	32	"	II Tr. In.
	9	18	"	III Oc. Re.		2	23	"	II Sh. In.
	10	14	"	III Ec. Dis.		6	24	P. M.	I Oc. Dis.
	11	57	"	III Ec. Re.		9	31	"	I Ec. Re.
17	12	54	A. M.	I Tr. In.	27	4	30	"	I Sh. In.
	1	38	"	I Sh. In.		5	46	"	I Tr. Eg.
	3	06	"	I Tr. Eg.		6	43	"	I Sh. Eg.
	10	10	P. M.	I Oc. Dis.		6	51	"	II Oc. Dis.
18	1	06	A. M.	I Ec. Re.		11	10	"	II Ec. Re.
	7	20	P. M.	I Tr. In.	29	4	12	"	II Tr. Eg.
	8	07	"	I Sh. In.		6	12	"	II Sh. Eg.
	9	33	"	I Tr. Eg.					

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

The Satellites of Saturn.



Mimas. Period 0 d 22.6 h.

	d	h				d	h				d	h		
Nov.	3	8.9	P. M.	E	Nov. 13	6.6	P. M.	W	Nov. 23	4.0	P. M.	E
	4	7.5	"	E	14	5.2	"	W	28	8.4	"	W
	5	6.1	"	E	15	3.9	"	W	29	7.1	"	W
	6	4.8	"	E	20	8.1	"	E	30	5.7	"	W
	7	3.5	"	E	21	6.7	"	E				
	12	7.9	P. M.	W	22	5.4	"	E				

The Satellites of Saturn.—(Continued.)

						d h							
					Enceladus.	Period 1	8.9.						
Nov.	2	8.4	A. M.	E	Nov. 11	10.6	P. M.	E	Nov. 21	12.9	P. M.	E	
	3	5.3	P. M.	E	13	7.5	A. M.	E	22	9.8	"	E	
	5	2.2	A. M.	E	14	4.4	P. M.	E	24	6.7	A. M.	E	
	6	11.1	"	E	16	1.3	A. M.	E	25	3.6	P. M.	E	
	7	7.9	P. M.	E	17	10.2	"	E	27	12.5	A. M.	E	
	9	4.8	A. M.	E	18	7.1	P. M.	E	28	9.4	"	E	
	10	1.7	P. M.	E	20	4.0	A. M.	E	30	6.3	P. M.	E	
						d h							
					Tethys.	Period 1	21.3.						
Nov.	2	1.5	P. M.	E	Nov. 13	9.5	P. M.	E	Nov. 25	5.4	"	E	
	4	10.9	A. M.	E	15	6.8	"	E	27	2.7	"	E	
	6	8.2	"	E	17	4.1	"	E	29	12.1	"	E	
	8	5.5	"	E	19	1.4	"	E	30	9.4	P. M.	E	
	10	2.8	"	E	21	10.8	A. M.	E					
	12	12.1	"	E	23	8.2	"	E					
						d h							
					Dione.	Period 2	17.7.						
Nov.	2	5.9	A. M.	E	Nov. 13	4.8	A. M.	E	Nov. 24	3.6	A. M.	E	
	4	11.7	P. M.	E	15	10.5	P. M.	E	26	9.2	P. M.	E	
	7	5.4	"	E	18	4.2	"	E	29	2.9	"	E	
	10	11.1	A. M.	E	21	9.9	A. M.	E					
						d h							
					Rhea.	Period 4	12.5.						
Nov.	5	11.5	A. M.	E	Nov. 14	12.4	P. M.	E	Nov. 23	1.5	P. M.	E	
	9	11.9	P. M.	E	19	12.9	A. M.	E	28	2.0	A. M.	E	
						d h							
					Titan.	Period 15	23.3.						
Nov.	3	8.3	A. M.	W	Nov. 15	8.5	A. M.	I	Nov. 27	4.5	A. M.	E	
	7	4.3	"	S	19	7.3	"	W					
	11	5.5	"	E	23	3.3	"	S					
						d h							
					Hyperion.	Period 21	7.6.						
Nov.	4	1	W		Nov. 13.9	E			Nov. 25.3	W			
		9.0	S		19.6	I			30.2	S			
						d h							
					Iapetus.	Period 79	22.1.						
Oct.	25.5	I			Nov. 15.2	W			Dec. 6.3	S			

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

Designation	Discovered by	at	Greenwich M. T.	h	m	R. A. h	m	Decl. °	′	Mag.
1904 OK	Götz	Heidelberg	1904 July 18	10	10.6	21	13.5	— 13	40	12.2
OL	Wolf	"	Aug. 2	10	30.1	21	25.3	— 6	52	11.9
OM	Wolf	"	Aug. 2	10	30.1	21	21.9	— 4	47	11.5
ON	Wolf	"	Aug. 3	10	43.1	21	10.6	— 6	58	13.2
OO	Wolf	"	Aug. 4	10	51.9	21	55.0	— 4	39	13.0
OP	Wolf	"	Aug. 14	13	13.0	22	24.9	+ 4	35	13.5
OQ	{Götz Kopff	"	Aug. 15	12	56.5	0	7.8	— 3	34	11.8

Comet and Asteroid Notes.—(Continued).

Encke's Comet.—Encke's Periodic Comet has been observed on its return by Kopff at Koenigstuhl on Sept. 11.529 Greenwich mean time in R.A. $1^h\ 46^m\ 16^s$ and Decl. $+ 25°\ 24'$. The comet is very faint.

A serious error was allowed to slip into the ephemeris of Encke's comet in our last number. The sign of the declination should be + instead of − . The same error is found in the ephemeris of Comet *a* 1904.

VARIABLE STARS.

Approximate Magnitudes of Variable Stars Sept. 10, 1904.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.		Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	
T Androm.	0	17.2	+26	26	15.5	*f*	R Camel.	14	25.1	+84	17	10	*d*
T Cassiop.	0	17.8	+55	14	9	*i*	R Bootis	14	32.8	+27	10	12.5	
R Androm.	0	18.8	+38	1	14	*f*	S Librae	15	15.6	−20	2	11.5	*d*
S Ceti	0	19.0	− 9	53	8		S Serpentis	15	17.0	+14	40	8	*i*
S Cassiop.	1	12.3	+72	5	16	*f*	S Coronae	15	17.3	+31	44	11.7	*d*
R Piscium	1	25.5	+ 2	22	7.5		S Urs. Min.	15	33.4	+78	58	8.8	*i*
R Trianguli	1	31.0	+33	50	8	*i*	R Coronae	15	44.4	+28	28	6.0	
U Persei	1	52.9	+54	20	11	*d*	V "	15	45.9	+39	52	10.7	*d*
R Arietis	2	10.4	+24	36	8.7	d	R Serpentis	15	46.1	+15	26	7.8	*d*
o Ceti	2	14.3	− 3	26	11		R Herculis	16	1.7	+18	38	9.5	*i*
S Persei	2	15.7	+58	8	8	*i*	R Scorpii	16	11.7	−22	42		*f*
R Ceti	2	20.9	− 0	38	12		S "	16	11.7	−22	39		*f*
U "	2	28.9	−13	35	6	*i*	U Herculis	16	21.4	+19	7	11.5	*d*
R Persei	3	23.7	+35	20	12		W Herculis	16	31.7	+37	32	11	*i*
R Tauri	4	22.8	+ 9	56	14	*f*	R Draconis	16	32.4	+66	58	12.5	
S "	4	23.7	+ 9	44		*f*	S Herculis	16	47.4	+15	7	7	
R Aurigæ	5	9.2	+53	28	13	*d*	R Ophiuchi	17	2.0	−15	58	7	
U Orionis	5	49.9	+20	10	9.7	*d*	T Herculis	18	5.3	+31	0	9.5	*i*
R Lyncis	6	53.0	+55	28	9	*i*	R Scuti	18	42.2	− 5	49	7	*d*
R Gemin.	7	1.3	+22	52		*f*	R Aquilae	19	1.6	+ 8	5	10.5	*d*
S Canis Min.	7	27.3	+ 8	32		*s*	R Sagittarii	19	10.8	−19	29	10.2	*i*
R Cancri	8	11.0	+12	2		*s*	S "	19	13.6	−19	12	11	*d*
V "	8	16.0	+17	36		*s*	R Cygni	19	34.1	+49	58	15	*d*
S Hydrae	8	48.4	+ 3	27		*s*	RT "	19	40.8	+48	32		*f*
T "	8	50.8	− 8	46		*s*	X "	19	46.7	+32	40	9.3	*i*
R Leo. Min.	9	39.6	+34	58		*s*	S Cygni	20	3.4	+57	42	12.6	*d*
R Leonis	9	42.2	+11	54		*s*	RS "	20	9.8	+38	28	7.7	*i*
R Urs. Maj.	10	37.6	+69	18	9.5	*d*	R Delphini	20	10.1	+ 8	47	8	
R Comae	11	59.1	+19	20	8		U Cygni	20	16.5	+47	35	7.5	
T Virginis	12	9.5	− 5	29		*s*	V "	20	38.1	+47	47	12.5	*d*
R Corvi	12	14.4	−18	42		*s*	T Aquarii	20	44.7	− 5	31	8	
Y Virginis	12	28.7	− 3	52		*f*	R Vulpec.	20	59.9	+23	26	8.5	*i*
T Urs. Maj.	12	31.8	+60	2	11	*d*	T Cephei	21	8.2	+68	5	9.7	*d*
R Virginis	12	33.4	+ 7	32		*s*	S "	21	36.5	+78	10	10.5	*d*
S Urs. Maj.	12	39.6	+61	38	11.5	*d*	S Lacertae	22	24.6	+39	48	10	*d*
U Virginis	12	46.0	+ 6	6	11.5	*d*	R "	22	38.8	+41	51	12	*d*
V "	13	22.6	− 2	39		*s*	S Aquarii	22	51.8	−20	53	12	
R Hydrae	13	24.2	−22	46		*s*	R Pegasi	23	1.6	+10	0	7	
S Virginis	13	27.8	− 6	41		*s*	S "	23	15.5	+ 8	22	13	
R Can. Ven.	13	44.6	+40	2	9.5	*d*	R Aquarii	23	38.6	−15	50	10.4	
S Bootis	14	19.5	+54	16	8.4	*i*	R Cassiop.	23	53.3	+50	50	12.8	*d*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

From observations made at the McCormick, Halsted and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U Cephei.

	d	h
Nov.	2	10
	4	21
	7	9
	9	21
	12	9
	14	21
	17	9
	19	20
	22	8
	24	20
	27	8
	29	20

Z Persei.

Nov.	1	2
	4	3
	7	5
	10	6
	13	7
	16	9
	19	10
	22	11
	25	13
	28	14

Algol.

Nov.	2	18
	5	15
	8	12
	11	9
	14	5
	17	2
	19	23
	22	20
	25	17
	28	13

λ Tauri.

Nov.	1	23
	5	22
	9	21
	13	20
	17	18
	21	17
	25	16
	29	15

R Canis Maj.

Nov.	2	2
	3	6
	4	9
	5	12
	6	16
	7	19
	8	22
	10	1
	11	5
	12	8

R Canis Maj.

	d	h
Nov.	13	11
	14	14
	15	18
	16	21
	18	0
	19	3
	20	7
	21	10
	22	13
	23	16
	24	20
	25	23
	27	2
	28	6
	29	9
	30	12

V Puppis.

	d	h
Nov.	1	23
	3	10
	4	20
	6	7
	7	18
	9	5
	10	16
	12	3
	13	14
	15	1
	16	12
	17	23
	19	10
	20	20
	22	8
	23	18
	25	5
	26	16
	28	3
	29	14

S Cancri.

Nov.	7	11
	16	23
	26	10

S Antliæ.

Nov.	1	23
	2	22
	3	21
	4	21
	5	20
	6	19
	7	19
	8	18
	9	17
	10	17
	11	16

S Antliæ.

	d	h
Nov.	12	15
	13	15
	14	14
	15	13
	16	13
	17	12
	18	11
	19	11
	20	10
	21	9
	22	9
	23	8
	24	7
	25	7
	26	6
	27	5
	28	5
	29	4
	30	3

S Velorum.

Nov.	4	9
	10	7
	16	6
	22	4
	28	2

W. Urs. Maj.

Nov.	1-3	10
	4-30	11

RR Velorum.

Nov.	1	22
	3	19
	5	15
	7	12
	9	8
	11	4
	13	1
	14	22
	16	18
	18	15
	20	11
	22	8
	24	4
	26	1
	27	21
	29	18

Z Draconis.

Nov.	1	21
	3	6
	4	14
	5	23
	7	8
	8	16
	10	1
	11	9

Z Draconis.

	d	h
Nov.	12	18
	14	3
	15	11
	16	20
	18	4
	19	13
	20	21
	22	6
	23	15
	24	23
	26	8
	27	16
	29	1
	30	9

Z Herculis.

Nov.	2	16
	4	13
	6	15
	8	12
	10	15
	12	12
	14	15
	16	12
	18	16
	20	12
	22	15
	24	12
	26	14
	28	11
	30	14

RS Sagittarii.

Nov.	1	13
	3	23
	6	8
	8	19
	11	5
	13	15
	16	1
	18	11
	20	21
	23	7
	25	17
	28	3
	30	13

RX Herculis.

Nov.	1	4
	2	1
	2	22
	3	20
	4	17
	5	15
	6	12
	7	9
	8	6

RX Herculis.

	d	h
Nov.	9	4
	10	1
	10	23
	11	20
	12	17
	13	15
	14	12
	15	9
	16	7
	17	4
	18	1
	18	23
	19	20
	20	17
	21	15
	22	12
	23	9
	24	7
	25	4
	26	1
	26	23
	27	20
	28	17
	29	15
	30	12

RV Lyræ.

Nov.	3	6
	6	20
	10	10
	14	1
	17	15
	21	6
	24	20
	28	10

U Sagittæ.

Nov.	4	0
	7	9
	10	18
	14	3
	17	12
	20	22
	24	7
	27	16

SY Cygni.

Nov.	3	22
	9	22
	15	22
	21	22
	27	22

SW Cygni.

Nov.	4	23
	9	13
	14	3

Minima of Variable Stars of the Algol Type.—Continued.

SW Cygni.		W Delphini.		VV Cygni.		VW Cygni.		Y Cygni.	
d	h	d	h	d	h	d	h	d	h
Nov. 18	17	Nov. 4	16	Nov. 9	23	Nov. 2	2	Nov. 13	21
23	6	9	11	11	11	10	13	15	12
27	20	14	6	12	22	18	23	16	21
		19	2	14	10	27	9	18	12
UW Cygni.		23	21	15	21			19	21
		28	17	17	8	Y Cygni.		21	12
Nov. 2	23			18	20			22	21
5	10	VV Cygni.		20	7	Nov. 1	21	24	12
9	21			21	19	3	12	25	21
13	8	Nov. 1	2	23	6	4	21	27	12
16	19	2	14	24	18	6	12	28	21
20	6	4	1	26	5	7	21	30	12
23	16	5	13	27	17	9	12		
27	3	7	0	29	4	10	21	UZ Cygni.	
30	14	8	12	30	15	12	12	Nov. 23	0

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$. The minimum occurs $1^h\ 40^m$ before the maximum.

d	h	d	h	d	h
Nov. 1- 5	6	Nov. 14-21	8	Nov. 29-30	10
6-13	7	22-29	9		

Maxima of UY Cygni.

Period $13^h\ 27^m\ 27^s.59$. The minimum occurs $1^h\ 55^m$ before the maximum.

d	h	d	h	d	h	d	h
Nov. 1	22	Nov. 9	18	Nov. 17	14	Nov. 25	11
3	0	10	21	18	17	26	14
4	3	12	0	19	20	27	17
5	6	13	3	20	23	28	20
6	9	14	6	22	2	29	22
7	12	15	9	23	5	31	1
8	15	16	11	24	8		

Maxima of RZ Lyræ.

Period $12^h\ 16^m\ 15^s.0$.

d	h	d	h	d	h	d	h
Nov. 1	13	Nov. 9	18	Nov. 17	22	Nov. 26	2
2	14	10	18	18	22	27	3
3	14	11	19	19	23	28	3
4	15	12	19	21	0	29	4
5	15	13	20	22	0	30	4
6	16	14	20	23	1		
7	17	15	21	24	1		
8	17	16	21	25	2		

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
W Geminorum	Nov. 1	11	Nov. 4	2	δ Cephei	2	7	3	16
V Velorum	1	12	2	11	X Cygni	2	17	8	22
U Sagittarii	2	0	4	23	TX Cygni	3	1	8	4

Variable Stars of Short Period not of the Algol Type.—(Continued.)

	Minimum.		Maximum.	
	d	h	d	h
ζ Geminorum	Nov. 3	19	8	19
κ Pavonis	3	20	7	15
S Crucis	3	21	5	9
T Velorum	3	22	5	7
Y Sagittarii	4	7	6	2
T Vulpeculae	4	14	5	23
SU Cygni	4	17	6	1
T Crucis	5	2	7	3
W Sagittarii	5	3	8	3
V Velorum	5	21	6	20
R Crucis	5	22	7	7
X Sagittarii	6	1	8	23
β Lyræ	6	5	9	12
η Aquilae	6	10	8	19
U Aquilae	6	14	8	18
U Vulpeculae	6	16	8	19
V Carinae	7	3	9	7
δ Cephei	7	15	9	0
S Muscae	7	23	11	10
S Sagittæ	8	4	11	14
W Virginis	8	7	16	12
SU Cygni	8	13	9	21
T Velorum	8	13	9	22
S Crucis	8	13	10	1
U Sagittarii	8	18	11	17
T Vulpeculae	9	1	10	10
W Geminorum	9	5	11	20
Y Sagittarii	10	2	11	21
V Velorum	10	6	11	5
R Crucis	11	18	13	3
T Crucis	11	20	13	21
SU Cygni	12	9	13	17
β Lyræ	12	16	15	18
W Sagittarii	12	17	15	17
δ Cephei	13	0	14	9
X Sagittarii	13	1	15	23
T Velorum	13	5	14	14
S Crucis	13	6	14	18
T Vulpeculae	13	10	14	19
η Aquilæ	13	14	15	23
U Aquilae	13	15	15	19
V Carinae	13	19	15	23
ζ Geminorum	13	23	18	23
V Velorum	14	15	15	14
U Vulpeculae	14	16	16	19
U Sagittarii	15	12	18	11
Y Sagittarii	15	20	17	15
SU Cygni	16	5	17	13
S Sagittae	16	13	19	20
W Geminorum	16	23	19	14
R Crucis	Nov. 17	14	18	23
S Muscae	17	15	21	2
TX Cygni	17	18	22	21
T Velorum	17	20	19	5
S Crucis	17	22	19	10
T Vulpeculae	17	22	19	7
δ Cephei	18	9	19	18
T Crucis	18	13	20	14
V Velorum	19	0	19	23
X Cygni	19	2	25	7
β Lyræ	19	3	22	10
X Sagittarii	20	1	22	22
SU Cygni	20	2	21	10
W Sagittarii	20	7	23	7
V Carinae	20	13	22	17
U Aquilae	20	15	22	19
η Aquilae	20	18	23	3
Y Sagittarii	21	15	23	10
U Sagittarii	22	6	25	5
T Vulpeculae	22	8	23	17
T Velorum	22	11	23	20
S Crucis	22	15	24	3
U Vulpeculae	22	15	24	18
V Velorum	23	9	24	8
R Crucis	23	10	24	19
δ Cephei	23	18	25	3
SU Cygni	23	22	25	6
ζ Geminorum	24	3	29	3
W Geminorum	24	17	27	8
S Sagittae	24	23	28	9
T Crucis	25	7	27	8
W Virginis	25	13	33	18
β Lyrae	25	14	28	16
T Monocerotis	25	23	34	8
T Vulpeculae	26	19	28	4
T Velorum	27	2	28	11
X Sagittarii	27	2	29	23
V Carinae	27	5	29	9
S Crucis	27	7	28	19
S Muscae	27	7	30	18
Y Sagittarii	27	9	29	4
U Aquilae	27	16	29	20
V Velorum	27	18	28	17
SU Cygni	27	18	29	2
W Sagittarii	27	22	30	22
η Aquilae	27	22	30	7
U Sagittarii	29	0	31	23
δ Cephei	29	2	30	11
R Crucis	29	6	30	15
U Vulpeculae	30	15	32	18

Twenty-five New Variables in Aquila.—In *A. N.* 3959 Professor Max Wolf, of Heidelberg gives the positions for 1900.0 of twenty-five new variables found in the constellation Aquila by comparing photographs taken in 1901 and 1903. Charts of all these variables are also given.

Designation	α 1900.0 h	m	s	δ 1900.0 °	′	″	Magnitude 1901	1903
64. 1903	19	27	48.78	+ 10	18	39.1	11.5	15
65. 1903		30	25.81	+ 7	02	14.1	14	12.5
66. 1903		33	11.20	+ 12	33	45.5	< 14	13
67. 1903		34	02.79	+ 12	02	21.7	13	< 14.5
68. 1903		34	20.15	+ 11	43	05.0	14.5	11
RV Aquilæ		35	56.75	+ 9	41	57.2	13	10.5
69. 1903		36	21.56	+ 7	11	02.8	14	11.5
70. 1903		38	06.17	+ 13	20	07.4	12.0	14.5
71. 1903		40	21.55	+ 8	12	11.7	11	< 15
72. 1903		41	47.05	+ 10	32	23.8	< 15	13.5
73. 1903		41	56.00	+ 10	13	06.1	< 15	14
74. 1903		42	22.61	+ 7	23	03.6	13.5	11.5
75. 1903		42	30.19	+ 12	14	19.5	11.5	< 15
76. 1903		42	49.38	+ 9	41	56.6	< 15.	12.0
77. 1903		43	39.78	+ 11	16	33.0	10.0	12.0
78. 1903		44	34.78	+ 12	07	07.4	11.0	13.0
79. 1903		46	00.21	+ 12	33	57.9	14	11.5
80. 1903		46	15.30	+ 12	58	00.0	11	< 14
81. 1903		48	42.38	+ 9	06	37.3	12	14
82. 1903		48	59.37	+ 10	44	05.1	12	13
83. 1903		49	06.26	+ 9	24	00.8	11	13
84. 1903		49	24.82	+ 7	21	01.4	12.5	11.5
85. 1903	19	49	32.68	+ 7	44	39.8	13	< 14
111. 1904	19	33	40.66	+ 10	22	02.1	13	< 15
112. 1904	19	34	12.46	+ 10	16	35.7	12.7	11.2

New Variables Discovered at Harvard.—*Circular* 79 of Harvard College Observatory gives the positions of seventy-six new variables found by Miss Leavitt in her examination of the Harvard photographic plates. Nine of them are in the region of the Orion Nebula, ten in the vicinity of η Carinæ and the remainder in the lesser Magellanic cloud in the southern heavens. Six other new variables are announced in *Circular* No. 80 and 152 in *Circular* No. 82, the latter number being all within the Large Magellanic cloud. The two long lists of variables in the Magellanic clouds have not been numbered by the Variable Star Committee and since the stars are all in the south polar regions of the sky we shall omit them here. The remaining variables are as follows:

Designation.	α 1900			δ 1900			Brightness.	
114. 1904 Orionis	5	24	01	— 6	11.3		11.6	< 15.4
115. 1904 "	5	25	13	— 4	33.9		12.4	13.1
116. 1904 "	5	27	05	— 5	00.7		10.0	11.0
117. 1904 "	5	27	08	— 2	53.7		9.0	11.4
118. 1904 "	5	30	25	— 5	24.8		11.4	12.5
119. 1904 "	5	30	33	— 6	51.7		12.8	13.5
120. 1904 "	5	32	22	— 9	38.6		8.0	10.2
121. 1904 "	5	33	32	— 2	48.0		11.6	13.2
122. 1904 "	5	33	34	— 2	47.5		11.4	14.2
133. 1904 Aurigæ	6	04.8		+ 43	11		Variation 2.5m	
123. 1904 Carinæ	10	16.8		— 60	57		10.0	11.5
124. 1904 "	10	20.9		— 60	24		10.2	12.2
125 1904 "	10	34.6		— 58	41		11.4	13.0
126. 1904 "	10	34.7		— 60	16		13.4	< 15.1
127. 1904 "	10	36.4		— 57	25		11.1	12.8
128. 1904 "	10	47.0		— 59	49		13.1	< 15.1
129. 1904 "	10	49.9		— 57	59		12.6	14.9
130. 1904 "	10	50.2		— 57	52		13.7	< 15.1
131. 1904 "	10	50.4		— 58	15		13.4	14.5
132. 1904 "	10	51.3		— 60	24		9.2	10.2
134. 1804 Ursæ maj.	12	35.8		+ 56	23		8.2	Varies 1.0m
135. 1904 Centauri	14	43.3		— 42	05			Varies 2.5m
136. 1904 Ophiuchi	17	29.8		+ 7	19		9.2	Varies 2.3m
137. 1904 Sagittarii	19	13.4		— 31	54		9.7	Varies 1.5m
138. 1904 Microscopii	21	17.5		— 41	07			Varies 3.0m

New Variables 139. 1904 Sagittarii and 140. 1904 Scuti.—These are two faint stars discovered by R. S. Dugan on photographs taken at Heidelberg. The first was below 13.5 or 14.5 magnitude on four plates taken in 1894 and 1901 but appears of the twelfth magnitude on June 21, 1904. The second appears on several plates as about 11.5 magnitude but on June 29, July 2, July 6, 1900 and June 21, 1900 was below 14.5. The positions are

	α 1900.0	δ 1900.0
139. 1904	$18^h\ 40^m\ 02^s.49$	$-17°\ 24'\ 14''.3$
140. 1904	$18\ 42\ 31\ 52$	$-12\ 14\ 22\ .5$

New Variable 141. 1904 Geminorum.—This was found by Professor Wolf of Heidelberg. It is invisible on plates taken Dec. 22, 1891, Jan. 7, 1896, Jan. 8, 1902, Jan. 17, 1603, but is found with magnitude 11.2 on Dec. 22, 1892 and 10.5 on April 20, 1903. Its position is

α 1900.0	δ 1900.0
$7^h\ 11^m\ 56^s.06$	$+24°\ 06'\ 05''.4$

It forms a small equilateral triangle with two eleventh magnitude stars.

New Variable 142. 1904 Pegasi.—In *A. N.* 3964 Professor K. Graff announces this new variable which is nearly on a parallel with and about 8° preceding the star BD + 11°,4757. It is the southern component of a close double star. On July 10, 1904 it was bright, about 9.4 magnitude, while on Aug. 2 it had sunk below its 11.5 mag. companion. Its position is

α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
$22^h\ 06^m\ 57^s$	$+11°\ 59'.1$	$22^h\ 09^m\ 09^s$	$+12°\ 12'.4$

Eleven New Variables 143-153. 1904 in Vulpecula.—By comparing two plates taken with the Bruce telescope at Heidelberg on June 27, 1903 and July 8, 1904, Professor Max Wolf has discovered eleven new variables in the eastern part of the constellation Vulpecula. The following table gives their positions for 1900.0 as measured by Professor Wolf and their approximate magnitudes as shown on the two plates:

	α 1900.0			δ 1900.0			June 27	July 8
	h	m	s	°	′	″	1903.	1904.
143. 1904	20	32	00.54	+23	31	00 2	13.2	11.2
144. 1904		32	18.88	+22	33	23.2	10.8	<15.
145. 1904		32	41.95	+25	57	55.3	15	12.0
146. 1904		34	29.77	+22	54	23.6	10.3	10.8
147. 1904		34	51.98	+23	08	34.4	10.3	14.
148. 1904		35	20.60	+26	54	44.2	14.0	11.9
149. 1904		37	25.50	+26	56	50.6	12.0	13.5
150. 1904		51	33.52	+26	17	50.7	11.0	<15
151. 1904		52	20.25	+23	11	35.5	11.9	<15
152. 1904		53	07.02	+27	28	13.9	9.9	11.2
153. 1904	20	53	23.29	+25	07	17.6	13.5	12.3

Charts of the vicinity of each of these variables are given in the *Astronomische Nachrichten* No. 3965. If these charts will be of value to any considerable number of our readers we shall be glad to publish them in a later number of POPULAR ASTRONOMY, but we shall not do so unless there is some expressed desire for them. We shall be glad to hear from the variable star observers on this point.

New Variable 154.1904 Cygni.—Professor W. Ceraski, in *A. N.* 3965, calls attention to a new variable in Cygnus, which is probably of the Algol type. On twenty plates, in the interval 1895-1903, the star is of about the same brightness, 9.3 magnitude, except on one taken Aug. 17, 1901, $11^h\,55^m - 14^h\,5^m$ Moscow mean time, when it was as faint as 12.5 magnitude. Visual observations of the star during this year indicate a constant brightness, about 9.3^m, except on Aug. 6 and 16 when it was noted to be faint. The star is BD $+41°\,3595$ and its position is

α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
$19^h\,59^m\,03^s.4$	$+41°\,10'.7$	$20^h\,00^m\,36^s.0$	$+41°\,18'.2$

GENERAL NOTES.

The Ninth Satellite of Mars.—We have received the extended paper by William H. Pickering on the ninth satellite of Mars. It deserves a fuller and more detailed notice than we now have space to give. A review of it will appear in our next issue.

The brilliant, detonating meteorite that is believed to have fallen not many miles from Northfield, Minn., July 26, 1904, has not yet been found, as far as we know. Professor N. H. Winchell's interesting notes elsewhere printed gives the best and latest information.

Photographic Work in the Rocky Mountains.—On account of the forest fires west of our observing station, we were unable to complete the work planned for the months of July and August last. By the generous courtesies of the general officers of the Great Northern Railway Company, we will return in a few days to do some more of the original plan needed before another year.

Manora Observatory.—In a circular accompanying the last issue of the *Astronomische Rundschau*, notice is given of the purpose to sell the Manora Observatory, instruments and library, at a moderate price, during the year 1905. The telescope is spoken of as one of great excellence. Apply to Manora-Sternwarte Lussenpiccolo (Istri).

Phœbe, Ninth Satellite of Saturn.—A search for Phœbe, the ninth satellite of Saturn was made on August 6, 1904, with the 40-inch Yerkes Telescope, by Professor Barnard, and Professor Turner of Oxford. An object was found resembling a star at 15.5 or 16.0 magnitude. Its apparent place $16^h\,0^m$, Greenwich Mean Time, was R. A. $21^h\,23^m\,1.0^s$, Decl. $-16°\,36'\,6''$. On Sept. 8, 1904, Professor Barnard found that this object was missing. There is no star in this position shown on photographs taken with the Bruce Telescope, on which Phœbe is visible. According to the ephemeris, (*Harvard Annals* LIII, 72), the approximate position of Phœbe on August 8, 1904, was R. A. $21^h\,23^m\,0^s$ Decl. $-16°\,36'\,4''$. This is, therefore, probably the first visual observation of the ninth satellite of Saturn. EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, *Bulletin*, No. *157*.
Cambridge, Mass., Sept. 8, 1904.

A telegram has been received at the Harvard College Observatory from Prof.

E. B. Frost at Yerkes Observatory stating that Phœbe, the ninth satellite of Saturn, was observed by Professor Barnard, September 12, at $12^h\ 36^m$ Greenwich Mean Time in R. A $21^h\ 12^m\ 29^s.5$, and Decl $-17°\ 25'\ 55''$. Its motion was toward the south-west and its magnitude 16.7.

Bulletin, No. 159.

CAMBRIDGE, Sept. 13, 1904.

The Crocker Eclipse Expedition of Lick Observatory.—William H. Crocker an intelligent and bountiful helper in many eclipse expeditions for Lick Observatory, will bear the expenses of three expeditions to observe the total solar eclipse of the Sun, August 30, 1905. As far as known the program is as follows:

Labrador. A photographic search for intramercurial planets, in the sky, $8\frac{1}{2}°$ wide, in the direction of the solar equator, from 4° below the Sun to 15° above it. To make photographs of the Corona with a camera of five inches aperature and forty feet focus.

Spain. Photographic intramercurial search, $9\frac{1}{4}°$ wide, in the direction of the solar equator, from 14° below to 14° above the Sun. To photograph the Corona as mentioned above. To observe the Corona for polarized light. To make spectrograms with moving plate holders for a continuous record between second and third contacts. To specialize in this kind of work on the "green line" and the "flash."

Egypt. Photographic intramercurial search same as in Labrador. The study of the Corona in the same way. Also the photography of the general spectrum of the Corona. Minor details of the work of these expeditions will doubtless be published later.

Constitution of Matter.—It is reported that there have been learned discussions at recent Cambridge Association meetings in regard to the constitution of matter. Some physicists holding that our sixty-six chemical elements should be greatly reduced to just what number no one dares to say. Some bold theorists outside of the association named are saying that all these elements so-called will be reduced ultimately to one. When the magnetic properties of matter are better understood and the principles of light rays are more fully comprehended, then chemically speaking, one element in nature endowed with polarity may be the basis of the new chemistry. But at the present time we are a long, long way from that state of physical science, and especially in spectroscopy.

The Lives of Tycho Brahe and Copernicus by Gassendo.—A short time since I picked up in a second-hand book store what I consider to be a rare book. It is the lives of Tycho Brahe and Copernicus, by Petro Gassendo. The book was written in Latin and published in Paris by Mathurini Dupius in the year 1654. It is therefore 250 years old. The pages are 9x6½ inches in size, and the book is bound in leather. It has full page portraits of Tycho and Copernicus, as well as cuts illustrating two different theories of the solar system.

The book opens with a preface of fifty pages, after which comes the life of Tycho in six chapters, preceded by a full page portrait, and occupying 258 pages. Then follow an appendix, the funeral oration, two eulogistic poems, an account of Tycho's work, including three pages of tables of his stellar observations, and an index—all taking up seventy-two pages. Next comes the life of Copernicus,

preceded by a full page portrait. This is very much shorter than Tycho's life, and occupies but fifty-one pages. Then follow short lives of George Peurbache and Johannes Regiomontani, occupying fifty-seven pages. An index of twelve pages finishes the book, making a total of 500 pages.

A former owner of the book has made some marginal corrections and notes in French and in Latin, which adds somewhat to its interest.

I send this brief account of the book, thinking it might be of interest to the readers of POPULAR ASTRONOMY, and in the hope that some reader may know something of the history of this work, which is a fine example of the printer's art of that time, and shows considerable enterprise on the part of some one to bring out a work of that kind. ALBERT I. BROOKS.

BROOKLYN, N. Y., Sept. 1904.

Clock Stopped by Lightning.—In *A. N.* 3964 Dr. Ernst Hartwig gives an interesting account of the stopping of the chief clock of the Bamberg Observatory by the influence of lightning. The clock is suspended on a pillar in the basement of the meridian room, the walls of which are of wrought iron. A lightning rod on the dome of the observatory is connected with the walls of the meridian room as well as with a metal plate deep in the ground. Four insulated wires imbedded in lead cables run from the clock to the meridian room, passing through the iron walls, two of the wires being connected with a microphone standing on the top of the clock and two with a contact apparatus in the clock. The clock is enclosed in a cylindrical, air-tight glass case, the metal plates at the top and bottom being connected by metal rods.

On the night of May 27 last, during a severe thunder storm, the lightning rod on the dome was struck twice within an interval of 46 seconds and the clock stopped 34 seconds after the second stroke of lightning. Dr. Hartwig at the time was noting the intervals between flashes of lightning and the succeeding reports of the thunder, and thus notes the exact times by the clock of these two flashes with the instantaneous reports as $12^h\ 57^m\ 01^s$ and $12^h\ 57^m\ 47^s$, Middle European time. The clock stopped at $12^h\ 58^m\ 21^s$.

The clock was taken down and carefully examined on the following day and no injury whatever was found, no sign of burning or fusion, and after being set up again it has run as well as before. The conclusion which Dr. Hartwig draws is that the lightning did not pass through the clock but took the course of least resistance through the metal case, and that the pendulum was stopped by being within a powerful electric field.

The clock used for transmitting time signals at Goodsell Observatory has twice been stopped by lightning, which fused the contact points together and thus caught the toothed wheel on the second's shaft, but the Bamberg instance seems to have been entirely different. In these instances at Northfield the lightning did not strike the observatory but the telegraph line some distance away. Recently we have tried to protect the observatory by placing lightning rods on several of the telegraph poles near the building. No serious shock has been noticed within the building since the placing of these lightning rods.

Photographic Brightness of Stars in the Pleiades Group.—In *A. N.* 3964 Mr. R. S. Dugan of the Observatory at Königstuhl-Heidelberg gives accurate positions and the photographic brightness of 350 faint stars in a por-

tion of the Pleiades group. The portion of the group includes about half a degree wide, east and west, and a degree long, north and south, extending from R. A. $3^h\ 41^m\ 30^s$ to $3^h\ 43^m\ 15^s$ and Decl. $+\ 23°\ 05'$ to $+\ 24°\ 15'$. In R. A. it extends approximately from Alcyone to Atlas and Pleione. The faintest stars included in the list are of the 15.3 magnitude on the scale employed. I find by comparing the chart which Mr. Dugan gives that these faintest stars are just barely visible on a photograph taken with the 8-inch Clark refractor at Goodsell Observatory with an exposure of four hours. Seven hour and sixteen hour exposures show many more stars.

Elogy on Sir Isaac Newton.—The English translation of Halley's Preface to the *Principia*, as reprinted in POPULAR ASTRONOMY, Vol. XII, pages 504-506, contains a few typographical errors. There should be exclamation marks after the fifth and sixth lines, viz:—

"Th" Almighty fix'd, when all things good he saw!
Behold the chaste, inviolable law!"

The next to the last line was wholly omitted. Therefore, I repeat the two concluding lines:—

"Newton, who reach'd th' insuperable line,
The nice barrier 'twixt human and divine."

With the above corrections, the reprint practically corresponds with the autographic copy sent me by Mr. Bolton. I deemed the English version a literary curiousity worthy of wider circulation, notwithstanding the opinion of so high an authority as Prof. S. P. Rigaud (d. 1839) that the translation "is not well done." (See "Historical Essay on the First Publication of Sir Isaac Newton's Principia," by S. P. Rigurd, page 86; Oxford, 1838.)

EUGENE FAIRFIELD MCPIKE.

ON HALLEY'S COMET, IN 1835.

P. BRONTE.*

Our blazing guest, long have you been,
To us, and many more, unseen;
Full seventy years have pass'd away
Since last we saw you, fresh and gay—
Time seems to do you little wrong—
As yet, you sweep the sky along,
A thousand times more glib and fast,
Than railroad speed or sweeping blast—
Not so—the things you left behind—
Not so—the race of human kind.
Vast changes in this world have been,
Since by this world you last were seen;
The child, who clapped his hands with joy,
And hailed thee as a shining toy,
Has pass'd, long since, that dusky bourne,
From whence no travellers return;
Or sinking now in feeble age,
Surveys thee as a hoary sage;
Sees thee, a mighty globe serene,

Wide hurried o'er the welkin sheen,
In nebulous or solid state,
For ends both wise, and good, and great:
Or, to adjust and balance true
The shining orbs of ether blue,
Lest, erring in the heavenly plane,
All should to chaos rush again;—
Or, if the sun, as Newton says,
Still issues forth substantial rays,
Emitting from his body bright,
Exhausting sparks of rapid light—
To give him back each spark and ray,
Well gather'd, on thy airy way;
Lest he should sink in wrinkled years,
And leave in night the rolling spheres.
Say, dost thou, then, all things that burn,
Give to the Sun in thy return?
And thus maintain his shining face
In all the pride of youthful grace?
If so, thou art less selfish far,
Than many another shining star—
Less selfish, far, than those below,
Who gaze upon thy brilliant glow;
For here, on earth, both one and all,
We try to rise on others' fall;
And think our lustre shines the best,
When dusky veils obscure the rest.
But Newton sage and others say,
The Sun doth play you *yea* and *nay*;
That, at each point of time, his force
Attracts, repels, thy fiery course;
In contradiction—strange to say—
Lest you should wander from your way,
And that, when he has got thy meed,
He sends you on your way with speed.
Alas! alas! should this be so?
How many suns are here below,
Save that they want both heat and light,
And never shine, by day or night—
Attract—repel—get all they can—
And part with nought to living man!
Some say thou art electric fire,
And hast a tail of plague and ire—
That all along thy airy way
You shed on men a baleful sway;
That on the nations near and far
You sow the seeds of bloody war.
Small need for these thy fatal arts;
For we abound in wrathful hearts,
And cunning heads, and blighting gales,
And martial hands, and fiery tails—
And swift to ill—for ill combine,

With ready skill, surpassing thine.

Thy course is chang'd, as sages say,
And thou hast run a novel way,
Just that the wond'ring world might own
Thou hast a will and way thine own.
In this, fair stranger, we're inclined
To follow thee, and have our mind—
Whate'er sarcastic mortals say,
For we have orbits where to move,
By impulse strong, of hate or love;
And we have ends to answer here,
Though in a dark and narrow sphere.
Since last this earth has seen thy face
Thou hast been wide in many a place,
And many suns and worlds hast known
Besides these orbs we call our own;—
Say, hast thou, in thy leisure hours,
E'er scrutinis'd a world like ours?—
E'er seen such thinking worms of clay,
Run wildly mad in such a way?—
So brief in life—so prone to ill—
So much averse to that great Will,
That speaks in truth and boundless might
And gave thee all thy speed, and light,
And very being—and has said
"Let all things be"—and they were made.

But thou art on thy course, I see,
And wilt not converse deign to me;—
Nor man nor angels by their force
Can for one moment stop thy course;—
The Mighty God Himself alone
Can rein thy speed, and guide thee on.
Then fare thee well, thou mighty star—
Go—do thy errand, near and far.
Ere thou dost here return again,
Few things that now are shall remain.
Tell distant worlds, on whom you shine,
The hand that made thee is divine,—
Round thy wide orbit shed thy rays,
In token of the highest praise
To God, who made thyself and all
The stars around this earthly ball—
Who shall beam forth, in glory bright,
When all creation sets in night.

* HAWORTH, October 20, 1835.

The poem reprinted above was published, perhaps for the first time, in *The Bradfordian*, for August 1st, 1861, and it again appeared in *The Bradford Weekly Telegraph* for August 6, 1904. Of each of these two publications, the former being rare and valuable, a copy has been sent me by Dr. Chas. F. Forshaw, M. A., LL. D., F. R. S. L., F. R. H. S., etc., etc., himself a prominent poet and scholar of Bradford, Yorkshire, England.

EUGENE FAIRFIELD MCPIKE.

CHICAGO, ILLINOIS, Sept. 14, 1904.

Correction.—Line 5, page 472 of our last issue should read "Notices of the Royal Astronomical Society there," and the word "pages," on line 6, should read "papers."

Pages 215-256 should be numbered 515-556.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

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Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. Appropriate blanks have been prepared and will be sent out generally to secure this important information. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

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